Jean Macé

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THE HISTORY

OF A

MOUTHFUL OF BREAD:

AND ITS EFFECT

ON THE

Organization of Men and Animals.

BY JEAN MACÉ.

TRANSLATED FROM THE EIGHTH FRENCH EDITION
BY MRS. ALFRED GATTY.

FIRST AMERICAN EDITION,
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BY JEAN MACÉ.

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EXTRACTS FROM THE PREFACE TO THE ENGLISH EDITION.

THE volume of which the following pages are a translation, has been adopted by the *University Commission at Paris among their prize books*, and has reached an eighth edition. Perhaps these facts speak sufficiently in its favor; but as translator, and to some extent editor, I wish to add my testimony to the great charm as well as merit of the little work. I sat down to it, I must own, with no special predilection in favor of the subject as a suitable one for young people; but in the course of the labor have become a thorough convert to the author's views that such a study—perhaps I ought to add, so pursued as he has enabled it to be—is likely to prove a most useful and most desirable one.

The precise age at which the interest of a young mind can be turned towards this practical branch of natural history is an open question, and not worth disputing about. It may vary even in different individuals. The letters are addressed to a *child*—in the original even to a *little girl*—and most undoubtedly, as the book stands, it is fit for any child's perusal who can find amusement in its pages: while to the rather older readers, of whom I trust there will be a great many, I will venture to say that the advantage they will gain in the subject having been so treated as to be brought within the comprehension and adapted to the tastes of a child, is pretty nearly incalculable. The quaintness and drollery of the illustrations with which difficult scientific facts are set forth will provoke many a smile, no doubt, and in some young people perhaps a tendency to feel themselves treated *babyishly;* but if in the course of the babyish treatment they find themselves almost unexpectedly becoming masters of an amount of valuable information on very difficult subjects, they will have nothing to complain of. Let such young readers refer to even a popular Encyclopædia for an insight into any of the subjects of the twenty-eight chapters of this volume—"The Heart," "The Lungs," "The Stomach," "Atmospheric Pressure," —no matter which, and see how much they can understand of it without an amount of preliminary instruction which would require half-a-year's study, and they will then thoroughly appreciate the quite marvellous ingenuity and beautiful skill with which M. Macé has brought the great leading anatomical and physical facts of life out of the depths of scientific learning, and made them literally comprehensible by a child.

. . . .

There is one point (independent of the scientific teaching) and that, happily, the only really important one, in which the English translator has had no change to make or desire. The religious teaching of the book is unexceptionable. There is no strained introduction of the subject, but there is throughout the volume an acknowledgment of the Great Creator of this marvellous work of the human frame, of the daily and hourly gratitude we owe to Him, and of the utter impossibility of our tracing out half his wonders, even in the things nearest to our senses, and most constantly subject to observation. M. Macé will help, and not hinder the humility with which the Christian naturalist lifts one veil only to recognise another beyond.

It will be satisfactory to any one who may be inclined to wonder how a lady can feel sure of having correctly translated the various scientific and anatomical statements contained in the volume, to know that the whole has been submitted to the careful revision of a medical friend, to whom I have reason to be very grateful for valuable explanations and corrections whenever they were necessary. In the same way the chapter on "Atmospheric Pressure," where, owing to the difference between French and English weights and measures, several alterations of illustrations, etc., had to be made, has received similar kind offices from the hands of a competent mathematician.

. . . .

MARGARET GATTY.

Ecclesfield, June, 1864.

NOTE TO THE AMERICAN EDITION.

In May '66, the seventeenth edition of this work was on sale in Paris. The date of Mrs. Gatty's preface, it will be observed, is June '64, and at that time, the eighth French edition only had been reached. That it should be a popular book and command a large sale wherever it is known, will not surprise any one who reads it: the only remarkable circumstance about it is, that it should not have been republished here long ere this. Even this may probably be accounted for, on the supposition that the title under which the translation was published in England, was so unmeaning—conveying not the slightest idea of the contents of the book—that none of our publishers even ventured to hand it over to their "readers" to examine.

The author's title, *The History of a Mouthful of Bread*, while falling far short of giving a clear notion of the entire scope of the work, is shockingly diluted and meaningless, when translated *The History of a Bit of Bread!*

To the translation of Mrs. Gatty, which is in the main an excellent one, for she has generally seized upon the idea of the author and rendered it with singular felicity, it may be very properly objected that she has taken some liberties with the text when there was any conflict of opinion between herself and her author, and has given her own ideas instead of his, which is, probably, what she refers to when she calls herself "to some extent editor."

The reader of this edition will, in all these cases, find the thought of the author and not that of his translator; for the reason that a careful examination of the original has convinced the publisher that in every instance the author was to be preferred to the translator, to say nothing of the right an author may have to be faithfully translated.

Besides making these restorations, the copy from which this edition was printed has been carefully compared with the last edition of the author and a vast number of corrections made, and in its present shape it is respectfully submitted and dedicated to every one (whose name is legion, of course) who numbers among his young friends a "*my dear child*" to present it to.

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THE HISTORY

OF A

MOUTHFUL OF BREAD.

LETTER I.

INTRODUCTION.

I AM going to tell you, my dear child, something of the life and nature of men and animals, believing the information may be of use to you in after-life, besides being an amusement to you now.

Of course, I shall have to explain to you a great many particulars which are generally considered very difficult to understand, and which are not always taught even to grown-up people. But if we work together, and between us succeed in getting them clearly into your head, it will be a great triumph to me, and you will find out that the science of learned men is more entertaining for little girls, as well as more comprehensible, than it is sometimes supposed to be. Moreover, you will be in advance of your years, as it were, and one day may be astonished to find that you had mastered in childhood, almost as a mere amusement, some of the first principles of anatomy, chemistry, and several other of the physical sciences, as well as having attained to some knowledge of natural history generally.

I begin at once, then, with the *History of a Mouthful of Bread,* although I am aware you may be tempted to exclaim, that if I am going to talk only about that, I may save myself the trouble. You know all about it, you say, as well as I do, and need not surely be told how to chew a bit of bread-and-butter! Well, but you must let me begin at the very beginning with you, and you have no notion what an incredible number of facts will be found to be connected with this chewing of a piece of bread. A big book might be written about them, were all the details to be entered into.

First and foremost—Have you ever asked yourself *why* people eat?

You laugh at such a ridiculous question.

"Why do people eat? Why, because there are bonbons, and cakes, and gingerbread, and sweetmeats, and fruit, and all manner of things good to eat." Very well, that is a very good reason, no doubt, and you may think that no other is wanted. If there were nothing but soup in the world, indeed, the case would be different. There might be some excuse then for making the inquiry.

Now, then, let us suppose for once that there *is* nothing in the world to eat but soup; and it is true that there are plenty of poor little children for whom there is nothing else, but who go on eating nevertheless, and with a very good appetite, too, I assure you, as their parents know but too well very often. Why do people eat, then, even when they have nothing to eat but soup? This is what I am going to tell you, if you do not already know.

The other day, when your mamma said that your frock "had grown" too short, and that you could not go out visiting till we had given you another with longer sleeves and waist, what was the real cause of this necessity?

What a droll question, you say, and you answer—"Because I had grown, of course."

To which I say "of course," too; for undoubtedly it was you who had outgrown your frock. But then I must push the question further, and ask—How had you grown?

Now you are puzzled. Nobody had been to your bed and pulled out your arms or your legs as you lay asleep. Nobody had pieced a bit on at the elbow or the knee, as people slip in a new leaf to a table when there is going to be a larger party than usual at dinner. How was it, then, that the sleeves no longer came down to your wrists, or that the body only reached your knees? Nothing grows larger without being added to, any more than anything gets smaller without having lost something; you may lay that down as a rule, once for all. If, therefore, nothing was added to you from without, something must have been added to you from within. Some sly goblin, as it were, must have been cramming into your frame whatever increase it has made in arms, legs, or anything else. And who, do you think, this sly goblin is?

Why, my dear, it is *yourself!*

Ay! Bethink you, now, of all the bread-and-butter, and bonbons, and gingerbread, and cakes, and sweetmeats, and even soup and plain food (the soup and plain food being the most useful of all) which you have been sending, day by day, for some time past, down what we used to call "the red lane," into the little gulf below. What do you think became of them when they got there? Well, they set to work at once, without asking your leave, to transform themselves into something else; and gliding cunningly into all the holes and corners of your body, became there, each as best he might, bones, flesh, blood, etc., etc. Touch yourself where you will, it is upon these things you lay your hand, though, of course, without recognizing them, for the transformation is perfect and complete. And it is the same with everybody.

Look at your little pink nails, which push out further and further every morning; examine the tips of your beautiful fair hair, which gets longer and longer by degrees; coming out from your head as grass springs up from the earth; feel the firm corners of your second teeth, which are gradually succeeding those which came to you in infancy; you have *eaten* all these things, and that no long time ago.

Nor are you children the only creatures who are busy in this way. There is your kitten, for instance, who a few months ago was only a tiny bit of fur, but is now turning gradually into a grown-up cat. It is her daily food which is daily becoming a cat inside her—her saucers of milk now, and very soon her mice, all serve to the same end.

The large ox, too, of whom you are so much afraid, because you cannot as yet be persuaded what a good-natured beast he really is, and how unlikely to do any harm to children who do none to him—that large ox began life as a small calf, and it is the grass which he has been eating for some time past which has transformed him into the huge mass of flesh you now see, and which by-and-by will be eaten by man, to become man's flesh in the same manner.

But, further, still: Even the forest trees, which grow so high and spread so wide, were at first no bigger than your little finger, and all the grandeur and size you now look upon, they have taken in by the process of eating. "What, *do trees eat?*" you ask.

Verily, do they; and they are, by no means, the least greedy of eaters, for they eat day and night without ceasing. Not, as you may suppose, that they crunch bonbons, or anything else as you do; nor is the process with them precisely the same as with you. Yet you will be surprised hereafter, I assure you, to find how many points of resemblance exist between them and us in this matter. But we will speak further of this presently.

Now, I think you must allow that there are few fairy-tales more marvellous than this history of bread and meat turning into little boys and girls, milk and mice turning into cats, and grass into oxen! And I call it a *history*, observe, because it is a transformation that never happens suddenly, but by degrees, as time goes on.

Now, then, for the explanation. You have heard, I dare say, of those wonderful spinning-machines which take in at one end a mass of raw cotton, very like what you see in wadding, and give out at the other a roll of fine calico, all folded and packed up ready to be delivered to the tradespeople. Well, you have within you, a machine even more ingenious than that, which receives from you all the bread-and-butter and other sorts of food you choose to put into it, and returns it to you changed into the nails, hair, bones and flesh we have been talking about, and many other things besides; for there are quantities of things in your body, all different from each other, which you are manufacturing in this manner all day long, without knowing anything about it. And a very fortunate thing this is for you;

for I do not know what would become of you if you had to be thinking from morning to night of all that requires to be done in your body, as your mother has to look after and remember all that has to be done in the house. Just think what a relief it would be to her to possess a machine which should sweep the rooms, cook the dinners, wash the plates, mend torn clothes, and keep watch over everything without giving her any trouble; and, moreover, make no more noise or fuss than yours does, which has been working away ever since you were born without your ever troubling your head about it, or probably even knowing of its existence! Just think of this and be thankful.

But do not fancy you are the only possessor of a magical machine of this sort. Your kitten has one also, and the ox we were speaking of, and all other living creatures. And theirs render the same service to them that yours does to you, and much in the same way; for all these machines are made after one model, though with certain variations adapted to the differences in each animal. And, as you will see by-and-by, these variations exactly correspond with the different sort of work that has to be done in each particular case. For instance, where the machine has grass to act upon, as in the ox, it is differently constructed from that in the cat which has to deal with meat and mice. In the same way in our manufactories, though all the spinning-machines are made upon one model, there is one particular arrangement for those which spin cotton, another for those which spin wool, another for flax, and so on.

But, further:

You have possibly noticed already, without being told, that all animals are not of equal value; or, at least, to use a better expression, they have not all had the same advantages bestowed on them. The dog, for instance, that loving and intelligent companion, who almost reads your thoughts in your eyes, and is as affectionate and obedient to his master as it were to be wished all children were to their parents—this dog is, as you must own, very superior, in all ways, to the frog, with its large goggle eyes and clammy body, hiding itself in the water as soon as you come near it. But again, the frog, which can come and go as it likes, is decidedly superior to the oyster, which has neither head nor limbs, and lives all alone, glued into a shell, in a sort of perpetual imprisonment.

Now the machine I have been telling you about is found in the oyster and in the frog as well as in the dog, only it is less complicated, and therefore less perfect in the oyster than in the frog; and less perfect again in the frog than in the dog; for as we descend in the scale of animals we find it becoming less and less elaborate—losing here one of its parts, there another, but nevertheless remaining still the same machine to all intents and purposes; though by the time it has reached its lowest condition of structure we should hardly be able to recognize it again, if we had not watched it through all its gradations of form, and escorted it, as it were, from stage to stage.

Let me make this clear to you by a comparison.

You know the lamp which is lit every evening on the drawing-room table, and around which you all assemble to work or read. Take off first the shade, which throws the light on your book—then the glass which prevents it smoking—then the little chimney which holds the wick and drives the air into the flame to make it burn brightly. Then take away the screw, which sends the wick up and down; undo the pieces one by one, un til none remain but those absolutely necessary to having a light at all—namely, the receptacle for the oil and the floating wick which consumes it.

Now if any one should come in and hear you say, "Look at my lamp," what would he reply? He would most likely ask at once, "What lamp?"—for there would be very little resemblance to a lamp in that mere ghost of one before him.

But to you, who have seen the different parts removed one after another, that wick soaked in oil (let your friend shake his head about it as he pleases) will still be the lamp to you, however divested of much that made it once so perfect, and however dimly it may shine in consequence.

And this is exactly what happens when the machine we are discussing is examined in the different grades of animals. The ignoramus who has not followed it through its changes and reductions cannot recognize it when it is presented to him in its lowest condition; but any one who has carefully observed it throughout, knows that it is, in point of fact, the same machine still.

This, then, is what we are now going to look at together, my dear little girl. We will study first, piece by piece, the exquisite machine within ourselves, which is of such unceasing use to us as long as we do not give it more than a proper share of work to perform. Do you understand? We will see what becomes of the mouthful of bread which you place so coolly between your teeth, as if when that was done nothing further remained to be thought about. We will trace it in its passage through every part of the machine, from beginning to end. It will therefore be simply only the *History of a Mouthful of Bread* I am telling you, even while I seem to be talking of other matters; for to make that comprehensible I shall have to enter into a good many explanations.

And when you have thoroughly got to understand the history of what you eat yourself, we will look a little into the history of what other animals eat, beginning by those most like ourselves, and going on to the rest in regular succession downwards. And while we are on the subject, I will say a word or two on the way in which vegetables eat, for, as you remember, I have stated that they do eat also.

Do you think this is likely to interest you, and be worth the trouble of some thought and attention?

Perhaps you may tell me it sounds very tedious, and like making a great fuss about a trifle; that you have all your life eaten mouthfuls of bread without troubling yourself as to what became of them, and yet have not been stopped growing by your ignorance, any more than the little cat, who knows no more how it happens than you do.

True, my dear; but the cat is only a little cat, and you are a little girl. Up to the present moment you and she have known, one as much as the other on this subject, and on that point you have therefore had no superiority over her. But she will never trouble herself about it, and will always remain a little cat. You, on the contrary, are intended by God to become something more in intelligence than you are now, and it is by learning more than the cat that you will rise above her in this respect. To learn, is the duty of all men, not only for the pleasure of curiosity and the vanity of being called learned, but because in proportion to what we learn we approach nearer to the destiny which God has appointed to man, and when we walk obediently in the path which God himself has marked out for us, we necessarily become better.

It is sometimes said to grown-up people, that it is never too late to learn. To children one may say that it is never too early to learn. And among the things which they may learn, those which I want now to teach you have the double merit of being, in the first place amusing, and afterwards, and above all, calculated to accustom you to think of God, by causing you to observe the wonders which He has done. Sure am I that when you know them you will not fail to admire them ; moreover I promise your mother that you will be all the better, as well as wiser, for the study.

FIRST PART.—MAN.

LETTER II.

THE HAND.

At the foot of the mountains, from whence I write to you, my dear child, when we want to show the country to a stranger, we commence by making him climb one of the heights, whence he may take in at a glance the whole landscape below, all the woods and villages scattered over the plain, even up to the blue line of the Rhine which stretches out to the distant horizon. After this he will easily find his way about.

It is to the top of a mountain equally useful that I have just led you. It has cost you some trouble to climb with me. You have had to keep your eyes very wide open that you might see to the end of the road we had to go together. Now then, let us come down and view the country in detail. Then we shall go as if we were on wheels.

And now let us begin at the beginning:

Well, doubtless, as the subject is eating, you will expect me to begin with the mouth.

Wait a moment; there is something else first. But you are so accustomed to make use of it, that you have never given it a thought, I dare say.

It is not enough merely that one should have a mouth, we must be able to put what we want within it. What would you do at dinner, for instance, if you had no hands?

The hand is then the first thing to be considered.

I shall not give you a description of it; you know what it is like. But what, perhaps, you do not know, because you have never thought about it, is, the reason why your hand is a more convenient, and consequently more perfect, instrument than a cat's paw, for instance, which yet answers a similar purpose, for it helps the cat to catch mice.

Among your five fingers there is one which is called the thumb, which stands out on one side quite apart from the others. Look at it with respect; it is to these two little bones, covered over with a little flesh, that man owes part of his physical superiority to other animals. It is one of his best servants, one of the noblest of God's gifts to him. Without the thumb three-fourths (at least) of human arts would yet have to be invented; and to begin with, the art not only of carrying the contents of one's plate to one's mouth, but of filling the plate (a very important question in another way) would, but for the thumb, have had difficulties to surmount of which you can form no idea.

Have you noticed that when you want to take hold of anything (a piece of bread, we will say, as we are on the subject of eating), have you noticed that it is always the thumb who puts himself forward, and that he is always on one side by himself, whilst the rest of the fingers are on the other? If the thumb is not helping, nothing remains in your hand, and you don't know what to do with it. Try, by way of experiment, to carry your spoon to your mouth without putting your thumb to it, and you will see what a long time it will take you to get through a poor little plateful of broth. The thumb is placed in such a manner on your hand that it can face each of the other fingers one after another, or all together, as you please; and by this we are enabled to grasp, as if with a pair of pincers, whatever object, whether large or small. Our hands owe their perfection of usefulness to this happy arrangement, which has been bestowed on no other animal, except the monkey, our nearest neighbor.

I may even add, while we are about it, that it is this which distinguishes the hand from a paw or a foot. Our feet, which have other things to do than to pick up apples or lay hold of a fork, our feet have also each five fingers, but the largest cannot face the others; it is not a thumb, therefore, and it is because of this that our feet are not hands. Now the monkey has thumbs on the four members corresponding to our arms and legs, and thus we may say that he has hands at the end of his legs as well as of his arms. Nevertheless, he is not on that account better off than we are, but quite the contrary. I will explain this to you presently.

To return to our subject. You see that it was necessary, before saying anything about the mouth, to consider the hand, which is the mouth's purveyor. Before the cook lights the fires the maid must go to market, must she not? And it is a very valuable maid that we have here: what would become of us without her?

If we were in the habit of giving thought to everything, we should never even gather a nut without being grateful to the Providence which has provided us with the thumb, by means of which we are able to do it so easily.

But however well I may have expressed it, I am by no means sure, after all, that I have succeeded in showing you clearly, how absolutely necessary our hand is to us in eating, and why it has the honor to stand at the beginning of the history of what we eat.

It still appears to you, I suspect, that even if you were to lose the use of your hands you would not, for all that, let yourself die of hunger.

This is because you have not attended to another circumstance, which nevertheless demands your notice—namely, that from one end of the world to the other, quantities of hands are being employed in providing you with the wherewithal to eat.

To go on further: Have you any idea how many hands have been put in motion merely to enable you to have your coffee and roll in the morning? What a number, to be sure, over this cup of coffee (which is a trifle in comparison with the other food you will consume in the course of the day); from the hand of the negro who gathered the coffee crop to that of the cook who ground the berries, to say nothing of the hand of the sailor who guided the ship which bore them to our shores. Again, from the hand of the laborer who sowed the corn, and that of the miller who ground it into flour, to the hand of the baker who made it into a roll. Then the hand of the farmer's wife who milked the cow, and the hand of the refiner who made the sugar; to say nothing of the many others who prepared his work for him, and I know not how many more.

How would it be, then, if I were to amuse myself by counting up all the hands that are wanted to furnish—

The sugar-refiner's manufactory,
The milkmaid's shed,
The baker's oven,
The miller's mill,
The laborer's plough,
The sailor's ship?

And even now is there nothing we have forgotten? Ah, yes! the most important of all the hands to you;—

the hand which brings together for your benefit the fruits of the labor of all the others—the hand of your dear mother, always active, always ready, that hand which so often acts as yours when your own is awkward or idle.

Now, then, you see how you might really manage to do without those two comparatively helpless little paws of yours (although there is a thumb to each), without suffering too much for want of food. With such an army of hands at work, in every way, to furnish provision for that little mouth, there would not be much danger.

But cut off your cat's fore paws—oh dear! what am I saying? Suppose, rather, that she has not got any, and then count how many mice she will catch in a day. The milk you give her is another matter, remember. Like your cup of coffee, that is provided for her by others.

Believe me, if you were suddenly left all alone in a wood, like those pretty squirrels who nibble hazel-nuts so daintily, you would soon discover, from being thus thrown upon your own resources, that the mouth is not the only thing required for eating, and that whether it be a paw or a hand, there must always be a servant to go to market for Mr. Mouth, and to provide him with food.

Happily, we are not driven to this extremity. We take hold of our coffee-biscuit between the thumb and forefinger, and behold it is on its road—Open the mouth, and it is soon done!

But before we begin to chew, let us stop to consider a little.

The mouth is the door at which everything enters. Now, to every well-kept door there is a doorkeeper, or porter. And what is the office of a well-instructed porter? Well, he asks the people that present themselves, who they are, and what they have come for; and if he does not like their appearance, he refuses them admittance. We too, then, to be complete, need a porter of this sort in our mouths, and I am happy to say we have one accordingly. I wonder whether you know him? You look at me quite aghast! Oh, ungrateful child, not to know your dearest friend! As a punishment, I shall not tell you who he is to-day. I will give you till to-morrow to think about it.

Meanwhile, as I have a little time left, I will say one word more about what we are going to look at together. It would hardly be worth while to tell you this pretty story which we have begun, if from time to time we were not to extract a moral from it. And what is the moral of our history to-day?

It has more than one.

In the first place it teaches you, if you never knew it before, that you are under great obligations to other people, indeed to almost everybody, and most of all perhaps to people whom you may be tempted to look down upon. This laborer, with his coarse smock-frock and heavy shoes, whom you are so ready to ridicule, is the very person who, with his rough hand, has been the means of procuring for you half the good things you eat. That workman, with turned-up sleeves, whose dirty black fingers you are afraid of touching, has very likely blackened and dirtied them in your service. You owe great respect to all these people, I assure you, for they all work for you. Do not, then, go and fancy yourself of great consequence among them—you who are of no use in any way at present, who want everybody's help yourself, but as yet can help nobody.

Not that I mean to reproach you by saying this. Your turn has not come yet, and everybody began like you originally. But I do wish to impress upon you that you must prepare yourself to become some day useful to others, so that you may pay back the debts which you are now contracting.

Every time you look at your little hand, remember that you have its education to accomplish, its debts of honor to repay, and that you must make haste and teach it to be very clever, so that it may no longer be said of you, that you are of no use to anybody.

And then, my dear child, remember that a day will come, when the revered hands that now take care of your childhood — those hands which to-day are yours, as it were—will become weak and incapacitated by age. You will be strong, then, probably, and the assistance which you receive now, you must then render to her, render it to her as you have received it—that is to say, with your hands. It is the mother's hand which comes and goes without ceasing about her little girl now. It is the daughter's hand which should come and go around the old mother hereafter—her hand and not another's.

Here again, my child, the mouth is nothing without the hand. The mouth says, "I love," the hand proves it.

LETTER III.

THE TONGUE.

Now, about this doorkeeper, or porter, as we will call him, of the mouth. I do not suppose you have guessed who he is ; so I am going to tell you.

The porter who keeps the door of the mouth is *the sense of taste.*

It is he who does the honors of the house so agreeably to proper visitors, and gives such an unscrupulous dismissal to unpleasant intruders. In other words, it is by his directions that we welcome so affectionately with tongue and lips whatever is good to eat, and spit out unhesitatingly whatever is unpleasant.

I could speak very ill of this porter if I chose ; which would not be very pleasant for certain little gourmands that I see here, who think a good deal too much of him. But I would rather begin by praising him. I can make my exceptions afterwards.

In the history I am going to give you, my dear child, there is one thing you must never lose sight of, even when I do not allude to it ; and that is, that everything we shall examine into, has been expressly arranged by God for the good and accommodation of our being in this world ; just as a cradle is arranged by a mother for the comfort of her baby. We must look upon all these things, therefore, as so many presents from the Almighty himself ; and abstain from speaking ill of them, were it only out of respect for the hand which has bestowed them.

Moreover, there is a very easy plan by which we may satisfy ourselves of the usefulness and propriety of these gifts—namely, by considering what would become of us if we were deprived of any one of them.

Suppose, for instance, that you were totally deficient in the sense of taste, and that when you put a piece of cake into your mouth, it should create no more sensation in you than when you held it in your hand?

You would not have thought of imagining such a case yourself, I am aware; for it never comes into a child's head to think that things can be otherwise than as God has made them. And in that respect children are sometimes wiser than philosophers. Nevertheless, we will suppose this for once, and consider what would happen in consequence.

Well, in the first place, you would eat old mouldy cake with just the same relish as if it were fresh: and this mouldy cake, which now you carefully avoid because it is mouldy, is very unwholesome food, and would poison you were you to eat a great deal of it.

I give this merely as an instance, but it is one of a thousand. And although, with regard to eatables, you only know such as have been prepared either in shops or in your mamma's kitchen, still you must be aware there are many we ought to avoid, because they would do no good in our stomachs, and that we should often be puzzled to distinguish these from others, if the sense of taste did not warn us about them. You must admit, therefore, that such warnings are not without their value.

In short, it is a marvellous fact that what is unfit for food, is *almost always* to be recognized as it enters the mouth, by its disagreeable taste; a further proof that God has thought of everything. Medicines, it is true, are unpleasant to the taste, and yet have to be swallowed in certain cases. But we may compare them to chimney-sweepers, who are neither pretty to look at, nor invited into the drawing-room ; but who, nevertheless, are from time to time let into the grandest houses by the porters —though possibly with a grimace—because their services are wanted. And in the same way medicines have to be admitted sometimes—despite their unpleasantness—because they,too, have to work in the chimney. Taste does not deceive you about them, however; they are not intended to serve as food. If any one should try to breakfast, dine, and sup upon physic he would soon find this out.

Besides, I only said *almost* always, in speaking of unwholesome food making itself known to us by its nasty taste ; for it is an unfortunate truth that men have invented a thousand plans for baffling their natural guardian, and for bringing thieves secretly into the company of honest people. They sometimes put poison, for instance, into sugar—as is too often done in the case of those horrible green and blue sugar plums, against which I have an old grudge, for they poisoned a friend whom I loved dearly in my youth. Such things as these pass imprudently by the porter, who sees nothing of their real character—Mr. Sugar concealing the rogues behind him.

Moreover, we are sometimes so foolish as not to leave the porter time to make his examination. We swallow one thing after another greedily, without tasting ; and such a crowd of arrivals, coming in with a rush, " forces the sentry," as they say ; and whose fault is it, if, after this, we find thieves established in the house ?

But animals have more sense than we have.

Look at your kitten when you give her some tit-bit she is not acquainted with—how cautiously and gently she puts out her nose, so as to give herself time for consideration. Then how delicately she touches the unknown object with the tip of her tongue, once, twice, and perhaps three times. And when the tip of the tongue has thus gone forward several times to make observations (for this is the great post of observation for the cat's porter as well as for ours), she ventures to decide upon swallowing, but not before. If she has the least suspicion, no amount of coaxing makes any difference to her; you may call "puss, puss," for ever; all your tender invitations are useless, and she turns away.

Very good; here then is one little animal, at least, who understands for what end she has received the sense of taste, and who makes a reasonable use of it. Very different from some children of my acquaintance, who heedlessly stuff into their mouths whatever comes into their hands, without even taking the trouble to taste it, and who would escape a good many stomach-aches, if nothing else, if they were as sensible as Pussy.

This is the really useful side of *the sense of taste;* but its agreeable side, which is sufficiently well known to you, is not to be despised either, even on the grounds of utility.

You must know, between ourselves, that eating would be a very tiresome business if we did not taste what we are eating; and I can well imagine what trouble mammas would have in persuading their children to come to dinner or tea, if it were only a question of working their little jaws, and nothing further. What struggles—what tears! And setting aside children, who are by no means always the most disobedient to the will of a good God, how few men would care to stop in the midst of their occupations, to go and grind their teeth one against another for half-an-hour, if there were not some pleasure attached to an exercise not naturally amusing in itself? Ay, ay, my dear child, were it not for the reward in pleasure which is given to men when they eat, the human race, who as a whole do not live too well already, would live still worse. And it is necessary that we should be fed, and well fed too, if we would perform properly here below the mission which we have received from above.

Yes, "reward" was the word I used. Now it seems absurd to you, perhaps, that it should be necessary to reward a man for eating a good dinner? Well, well, GOD has been more kind to him, then, than you would be. To every duty imposed by Him upon man, He has joined a pleasure as a reward for fulfilling it. How many things should I not have to say to you on this subject, if you were older? For the present, I will content myself with making a comparison.

When a mother thinks her child is not reasonable enough to do, of her own accord, something which it is nevertheless important she should do, as learning to read, for instance, or to work with her needle, &c., she comes to the rescue with rewards, and gives her a plaything when she has done well. And thus GOD, who had not confidence enough in man's reason to trust to it alone for supplying the wants of human nature, has placed a plaything in the shape of pleasure after every necessity; and in supplying the want, man finds the reward.

You will hardly believe that what I have here explained to you so quietly by a childish comparison, has been, and alas! still is, the subject of terrible disputes among grown-up people. If hereafter they reach your ears, remember what I have told you now, viz., that the pleasure lodged in the tongue and its surroundings, is a plaything, but a plaything given to us by GOD; and that we must use it accordingly.

If a little girl has had a plaything given to her by her mother, would she think to please her by breaking it or throwing it into a corner? No, certainly not: she would know that in so doing she would be going directly against her mother's intentions and wishes. Nevertheless she would amuse herself with it in play hours, with an easy conscience, and, if she is amiable, she will remember while she does so, that it comes to her from her mother, and will thank her at the bottom of her heart.

It is the same with man, of whose playthings we are speaking.

But, moreover, this little girl (it is taken for granted that she is a good little girl) will not make the plaything the business of her whole day, the object of all her thoughts; she will not forget everything for it, she will leave it unhesitatingly when her mamma calls her. Neither will she wish to be alone in her enjoyments, but will gladly see her little friends also enjoy similar playthings, because she thinks that what is good for her must be good for others too.

It is thus that man should do with his playthings; but, alas! this is what he does not by any means always do with them, and hence a great deal has been said against them. Little girls, in particular, are apt to fail on this point, and that is how the dreadful word *gluttony* came to be invented. For the same reason, also, people get punished from time to time; such punishments being the consequence of the misuse I speak of.

If people who call to see your mamma were, instead of going straight up stairs to her, to establish themselves at the lodge with the porter, and stay there chatting with him, do you think she would be much flattered by their visits? And yet this is exactly what people do who, when eating, attend only to the porter. He is so pleasant, this porter; he says such pretty things to you, that you go on talking to him just as if he were the master of the house, who, meanwhile, has quite gone out of your head.

You heap sugar-plums upon sugar-plums, cakes upon cakes, sweetmeats upon sweetmeats — everything that pleases the porter, but is of no use whatever to the master of the house. And then what happens? The master gets angry sometimes, and no wonder. Mr. Stomach grows weary of these visits, which are of no use to him. He rings all the bells, makes no end of a noise in the house, and forces that traitor of a porter who has engrossed all his company, to do penance. You are ill—your mouth is out of order—you have no appetite for anything. The mamma has taken away the plaything which has been misused, and when she gives it back, there must be great care taken not to do the same thing over again.

I have thought it only right, my dear child, in telling you the history of eating, to give to this little detail of its beginning, a place proportioned to your interest in it. You see by what I have said, that you are not altogether wrong in following your taste; but neither must it be forgotten that this part of the business is not in reality the most important; that a plaything is but a plaything, and that the porter is not the master of the house.

Now that we have made our good friend's acquaintance, we will wish him farewell, and I will presently introduce you to his companions of the antechamber, who are ranged on the two sides of the door, to make the toilettes for the visitors who present themselves, and to put them in order for being received in the drawing-room. You will see there some jolly little fellows, who are also very useful in their way, and whose history is no less curious. They are called TEETH.

LETTER IV.

THE TEETH.

When you were quite little, my dear child, and still a nursling, you had nothing behind your lips but two little rosy bars, which were of no service for gnawing an apple, as they were not supplied with teeth. You had no need of these then, since nothing but milk passed your lips, neither had your nurse bargained for your having teeth to bite with. You see that God provides for everything, as I have already said, and shall often have occasion to point out to you.

But by degrees the little infant grew into a great girl, and it became necessary to think of giving her something more solid than milk to eat; and for this purpose she required teeth. Then some little germs, which had lain dormant, concealed within the jaws, awoke one after another, like faithful workmen when they hear the striking of the clock. Each set to work in his little cell, and with the help of some phosphorus and some lime, it began to make itself a kind of white armour, as hard as a stone, which grew larger from day to day.

You know what lime is; that sort of white pulp which you have seen standing in large troughs where the masons are building houses, and which they use in making mortar; it is with this that your little masons build your teeth.

As to phosphorus, I am afraid you may never have seen any; but you may have heard it spoken of. It is sold at the druggist's in the form of little white sticks, about as thick as your finger; they have a disagreeable, garlicky smell, and are obliged to be kept in jars of water, because they seize every opportunity of taking fire; so I advise you, if ever you do see any phosphorus, not to meddle with it—for in burning, it sticks closely to the skin, and there is the greatest difficulty in the world in extinguishing it, and the burns it makes are fearful. I give you this caution, because phosphorus possesses a very curious property, which might attract little girls. Wherever it is rubbed, in the dark, on a door, or on a wall, it leaves a luminous trail of a very peculiar appearance, which has been called phosphorescent, from the name of the substance which produces it. And in this way one can write on walls in letters of fire, to the terror of cowards. Now, come; if you will promise to be very wise, and only to make the experiment when your mamma is present, I will teach you how to make phosphorescent lights without having to go to the druggist's! There is a small quantity of phosphorus in lucifer matches, which their garlicky smell proves. Rub them gently in the dark on a bit of wood, and you will see a ray of light which will shine for some moments. But mind, you must not play at that game when you are alone; it is a dangerous amusement, and one hears every day of terrible accidents caused by disobedient children playing with lucifer matches. And while we are on the subject, let me warn you against putting them into your mouth. Phosphorus is a poison, and such a powerful one that people poison rats with bread-crumb balls in which it has been introduced.

"Oh dear me! and that poison makes part of our teeth?"

Exactly so, and it even forms part of all our bones, and of the bones of all animals ; the best proof of which is, that the phosphorus of lucifer matches has been procured out of bones from the slaughter-house. One could make it from the teeth of little girls if one could get enough of them.

Now I see what puzzles you, and well it may. You are asking yourself how those little tooth-makers, the gums, get hold of this terrible phosphorus, which is set on fire by a mere nothing, and which we dare not put into our mouths ; where do they find the lime which I also protest is not fit to eat, and yet of which we have stores from our heads to our feet?

It is very surprising, too, to think of its being forthcoming in the jaws just when it is wanted there.

You begin to perceive that there are many things to be learnt before we come to the end of our history, and that we find ourselves checked at every step ; now listen, for we are coming to something very important.

In distant country-seats, where people are thrown entirely upon their own resources, they must be provided beforehand with all that is requisite for repairing the building ; and there is, accordingly, a person called a steward, who keeps everything under lock and key, and distributes to the workmen whatever materials they may require. Thus, the steward gives tiles to the slater, planks to the carpenter, colors to the painter, lime and bricks to the mason—the very same lime that we have in our teeth—in fact, he has got everything that can be wanted in his storehouse, and it is to him that every one applies in time of need.

Now our body also is a mansion, and has its steward too. But what a steward—how active! what a universal genius! how inefficient by comparison are the stewards of the greatest lords! He goes, he comes, he is everywhere at once; and this really, and not as we use the phrase in speaking of a merely active man: for the *being everywhere at once* is in this case, a fact. He keeps everything, not in a storehouse, but what is far better, in his very pockets, which he empties by degrees as he goes about, distributing their contents without ever making a mistake, without stopping, without delaying; and returns to replenish his resources in a ceaseless, indefatigable course, which never flags, night nor day. And you can form no idea how many workmen he has under his orders, all laboring without intermission, all requiring different things—not one of them pausing, even for a joke!—not even to say—"Wait a moment;" —they do not understand what waiting means: he must always keep giving, giving, giving. By and by we shall have a long account to give of this wonderful steward, whose name, be it known, if you have not already guessed it, is Blood.

It is he who, one fine day when he was making his round of the jaws, found those little germs I spoke of, awake and eager for work; and he began at once to start them with materials. He knew that phosphorus and lime were what they needed: he drew phosphorus and lime therefore out of his pockets,—and, to be very exact, some other little matters too,—but these were the most important; but I cannot stop to tell you everything at once.

Now, where did the blood obtain this phosphorus and lime?

I expected you to ask this, but if you want everything explained as we go along, we shall not get very far. In fact, if I answer all your questions I shall be letting out my secret too soon, and telling you the end of my story almost before it is begun.

So be it, however ; perhaps you will feel more courage to go on, when you know where we are going.

The steward of a country-house distributes tiles, planks, paint, bricks, lime ; but none of these things are his own, as you know ; he has received them from his master : and, in the same way, our steward has nothing of his own : everything he distributes comes from the master of the house, and as I have already told you, this master is the stomach. As fast as the steward distributes, therefore, must the master renew the stores—and renew them all, for unless he does this, the work would stop. In proportion as the blood gives out on all sides the contents of his pockets, the stomach must replenish them, and fill them with everything necessary, or there would be a revolution in the house. Now, as there can be nothing in the stomach but what has got into it by the mouth, it behooves us to put into the mouth whatever is needed for the supply of our numerous workmen ; and this is why we eat.

I perceive that I have plunged here into an explanation out of which I shall not easily extricate myself, for I can guess what you are going to say next. When you began to cut your teeth, you had eaten neither phosphorus nor lime, as nothing but milk had entered your mouth.

That is true. Neither then, nor since then, have you eaten those things, and what is more, I hope you never will. And yet both must have got into your mouth, for without them your teeth could never have grown. How are we to get out of this puzzle ?

Suppose now, for a moment, that instead of phosphorus and lime, the little workmen in your jaws had asked the blood for sugar to make the teeth with. Fortunately this is only a supposition ; otherwise I should be in great fear for the poor teeth : they would not last very long. Suppose, further, that instead of your eating the lump of sugar which was destined to turn into a tooth, your mamma had melted it in a glass of water, and had given it to you to drink ; you could not say you had eaten sugar, and yet the sugar would really have got into your stomach, and there would be nothing very wonderful if the stomach had found it out and given it to the blood, and the blood had carried it off to the place where it was wanted. Now, allowing that the lump of sugar was very small, and the glass of water very large, the sugar might have passed without your perceiving it, and yet the tooth would have grown all the same, and without the help of a miracle.

And this is how it was. In the milk which you drank as a baby there were both phosphorus and lime, though in very small quantities. There were many other things besides ; everything of course that the blood required for the use of its work-people, because at that time the stomach was only receiving milk, and yet all the work was going on as usual.

And therefore, my dear child, whenever in the course of our studies, you hear me describe such and such a thing as being within us, say quietly to yourself, " that also was in the milk which nourished me when I was a baby."

Of course, the same things are in what you eat now ; only now they come in a form more difficult to deal with, and the labor of detaching them from the surrounding ingredients is much greater. The whole business indeed of this famous machine which we are studying consists in unfastening the links which hold things together, and in laying aside what is useful, to be sent to the blood divested of the refuse. The stomach was too feeble in your infancy to have encountered the work it has to do now. It is for this reason that God devised for the benefit of little children that excellent nourishment—milk—which contains, all ready for use, every ingredient the blood wants; and is almost, in fact, blood ready made.

Only think, my child, what you owe to her who gave you this nourishment! It was actually her blood she was giving you; her blood which entered into your veins, and which wrought within you in the wonderful way which I have been describing. Other people gave you sugar-plums, kisses, and toys; but she gave you the teeth which crunched the sugar-plums, the flesh of the rosy cheeks which got the kisses, and of the little hands which handled the toys. If ever you can forget this, you are ungrateful indeed!

Now, beware of going on to ask me how we know that there are so many sorts of things in milk, or I shall end by getting angry. Question after question; why, you might drive me in this way to the end of the world, and we should never reach the point we are aiming at. We have already traveled far away from the teeth, concerning which I wanted to talk to you at this time, but our lesson is nearly over and we have scarcely said a word about them! One cannot learn everything at once. Upon the point in question you must take my word; and as you may believe, I would not run the risk of being contradicted before you, by those who have authority on the subject.

Let it suffice you, for to-day, to have gained some idea of the manner in which the materials which constitute our bodies are manufactured within us. We have got at this by talking of the teeth; to-morrow, it may be the saliva, the next day something else. What I have now told you will be of use all the way through, and I do not regret the time we have given to the subject. If you have understood that well, the time has not been lost.

LETTER V.

THE TEETH (*continued.*)

My thoughts return involuntarily to the subject I last explained to you, my dear child, and I find that I have a great deal to say about it still.

You see now, I hope, that we have something else to consult besides a dainty taste when we are eating; and that if we are to work to any good purpose we must think a little about this poor blood; who has so much to do, and who often finds himself so much at fault, when we send him nothing but barley-sugar and biscuits for his support. It is not with such stuff as that, as you may well imagine, that he can be enabled to answer satisfactorily to the constant demands of his little workmen, and we expose him to the risk of getting into disgrace with them, if we furnish him with no better provisions.

And who is the sufferer? Not I who am giving you this information, most certainly.

Now, when children hesitate about eating plain food, and fly from beef to rush at dessert, they act as a man would do who should begin to build by giving his workmen reeds instead of beams, and squares of gingerbread instead of bricks. A pretty house he would have of it; —just think!

On the contrary, what your mother asks you to eat, my dear little epicure, is sure to be something which contains the indispensable supplies for which your blood is craving; for people knew all about this by experience long before they could explain the why and the wherefore. But now that you are so much better informed than even the most learned men were a century ago, pouting and wry faces at table are no longer excusable, and I should be sadly ashamed of you if I should hear you continued to make them.

And this is what I was more particularly thinking of just now, when I took up my pen again. No doubt it is very amusing to be able to look clearly into one's frame, and see what goes on inside, but the amusement anything affords is the least important part of it; you have begun to find this out already, and you will find it out more and more every day. What seems to me one of the great advantages of the study we have begun together is, that at every step you take you will meet with the most practical and useful instruction, as well as the most unanswerable reasons for doing what your parents ask you to do every day.

To obey without knowing why is certainly possible, and may be done happily enough. But we obey more readily and easily when we understand the reason for doing so; and a duty which one can satisfy oneself about, forces itself upon one as a sort of necessity. And what can throw a stronger light on our duties than a thorough acquaintance with ourselves?

It is upwards of two thousand two hundred years ago (and that is not yesterday, you must own!) since one of the greatest minds of the world—Socrates—never forget that name—taught his disciples, as a foundation precept, this apparently simple maxim, "Know thyself." He meant this, it is true, in a much higher sense than we are aiming at in these conversations of ours, but his rule is so practical, that although you have only as yet taken a mere peep into one small corner of self-knowledge, you find, if I am not much mistaken, that your heart has beaten once or twice rather faster than it did before. Was I wrong, in saying from the beginning, that we become better as we grow in knowledge? Is it not true that you have felt more tenderly than ever towards her who nourished you with her milk, since I explained to you the value of milk; and that you have kissed your mother's hand all the more lovingly since you heard my history of the hand? To tell you the truth, if you had not done so, I should have been dissatisfied both with you and myself.

And wait! While we are talking thus, another thought has come into my head about hands and nurses, which I must tell you of.

There is something of the nurse, my child, in those who take the best fruits of their intellect and heart, and transform them, as it were, into milk, in order that your infant soul may receive a nourishment it will be able to digest without too much effort. In this way their very soul enters into you, and it is but fair that you should reward them as they deserve. Young as you are, too, you have a recompense in your power: one more acceptable even than Academic prizes—of which it is indispensable not to be too avaricious—you can give them your love.

Besides, it is not only hands but heads that are at work for you, and of these many more than you suppose; and your debt of gratitude is as much due to the one as to the other.

Perhaps my first letter may have led you to suppose that I was inclined to laugh at what I called learned men; and they are perhaps a little to blame for not thinking often enough about little girls; but nevertheless these men are of the greatest use to them in an indirect way. You owe them much, therefore, and without them could have known nothing of what I am teaching you. It is very grand for us, is it not, to know that there is phosphorus and lime in our teeth? But it took generations of learned men, and investigations and discoveries without end, and ages of laborious study, to extract from nature this secret which you have learnt in five minutes. And whatever others you may learn hereafter, remember that it is the same story with all. While profiting, therefore, at your ease, by all these conquests of science, I would have you hold in grateful recollection those who have gained them at so much cost to themselves: almost always at the expense of their fortune, sometimes at the peril of their lives.

There they are, observe, a little knot of men with no sort of outward pretension. They speak a language which scares children away. They weigh dirty little powders in apothecaries' scales; steep sheets of copper in acid-water; and watch air-bubbles passing through bent glass tubes, some of which are as dangerous as cannon balls. They scrape old bones, and slice scraps no bigger than a pin's head. They keep their eyes fixed for hours upon things they are examining through microscopes of a dozen glasses, and when you go to see what they are looking at, you find nothing at all. To see them at work, in what they call their laboratories, you would say that they were a set of madmen. But at the end, it is found, some fine day, that they have changed the face of the earth; have worked revolutions before which emperors and kings bow in respect; have enriched nations by millions at a time; have revealed to the human race, divine laws of which it had hitherto been ignorant; finally, have furnished the means of teaching little boys and girls some very curious things, which will make them more agreeable as well as reasonable. And this is a benefit not to be despised, since these children are destined one day to become fathers and mothers, and so to govern the next generation; and the better they themselves are instructed, the better this will be done.

But now let us go back to the poor teeth, whom we seem to have forgotten altogether. However, we knew very well that they would not run away meantime.

I told you before that it was their business to dress and prepare whatever was presented to them, but the reception they bestow is not one which would suit every body's taste, for it consists in being made mince-meat of And in order to do their work in the best way possible they divide their labor; some cut up, others tear, and others pound.

First, there are those flat teeth in front of the two jaws, just below the nose. Touch yours with the tip of your finger; you will find that they terminate in sharp-edged blades, like knives. These are called *incisors*, from the Latin word *incidere*, which means to cut, and it is with them we bite bread and apples, where the first business is to cut. It is with the same teeth that lazy little girls bite their thread, when they will not take the trouble to find their scissors; and, by the by, this is a very bad trick, because by rubbing them one against another in this manner we wear them out, and, as you will soon discover, worn-out teeth never grow again.

The next sort are those little pointed teeth, which come after the *incisors*, on each side of both jaws. You will easily find them; and if you press against them a little, you will feel their points. If we call the first set the knives of the mouth, we may call these its forks. They serve to pierce whatever requires to be torn, and they are called *canine* teeth, from the Latin word *canis*, a dog, because dogs make great use of them in tearing their food. They place their paws upon it, and plunging the canine teeth into it, pull off pieces by a jerk of the head. Look into the mouth of papa's dog: you will recognize these teeth by their rather curved points. They are longer than the rest, and are called fangs. I do not know, after all, why they have chosen to name these teeth *canine*, as all carnivorous animals have the same fangs, and in the lion, the tiger, and many other species, they are much more developed and sharper than in the dog. In cats they are like little nails. However, the name is given, and we cannot alter it.

The last teeth, which are placed at the back of the jaw, are called molars, from the Latin word *mola*, which means a millstone.

You must be prepared to meet with several Latin words as we go on; but never mind; this will give you the opportunity of learning a little Latin, and so of keeping your brother in order, if he ever looks down upon you because he is learning Latin at school. Formerly, all learned men wrote in Latin, and as they ruled supreme in all such subjects as those we are discussing, they gave to everything such names as they pleased, without consulting the public, who did not just then trouble their heads about the matter. Now they give Greek names, which can hardly be called an improvement; but if they ever wish to attract the attention of little girls they must translate their hard words into our own language.

To return to our grinders: they perform the same office as a miller's millstone; that is to say, they grind everything that comes in their way. These teeth have flat, square tops, with little inequalities on the surface, which you can feel the moment you lay your finger on them. These are the largest and strongest of the three sets, and with them we even crack nuts, when we prefer the risk of breaking our teeth to the trouble of looking for the nut-crackers!

Now, I will answer for it that you cannot explain to me why we always place what is hard to break between the *molars*, and never employ the *incisors* in the work? And yet everybody does this alike—from the child to the grown-up man—and all equally without thinking of what they are doing.

I will tell you the reason, however, if you will first tell me why, when you are going to snip off the tip of your thread (which offers very little resistance), you do it with the point of your scissors; whereas you put any tough thing which is likely to resist strongly (a match, for instance) close up to their hinge; particularly if you have no scruple about spoiling the scissors, by the way!

If you were a grown-up lad, and I were teaching you natural philosophy, I should have here a fine opportunity for explaining what is called *the theory of the lever*. But I think *the theory of the lever* would frighten you; so we must get out of the difficulty in some other way.

I find, however, that I have been joking so much as I went along, that I have but little space left, and feel quite ashamed of myself. We seem quite unlucky over these teeth.

I have already been scolded by people who are not altogether wrong in accusing me of losing my time in chattering, first of one thing and then of another. They complain that by thus nibbling at every blade of grass on the way-side we shall never get to the end of our journey; and there is some truth in what they say. Still, I will whisper to you in excuse that I thought we might play truant a little bit while we were on familiar ground, where naturally you were sure to feel a particular interest in everything. The hand, the tongue, the teeth—these are all old friends of yours—and I thought you would like to hear all about them. By-and-bye we shall be in the little black hole, and then we shall get on much more rapidly.

LETTER VI.

THE TEETH (*continued*).

I LEFT off at the *molars*, which are the teeth one selects to crack nuts with; and if I remember rightly, we talked about different ways of cutting with scissors.

Let us look at the subject from a distance, that we may understand it more clearly. Let us imagine a horse drawing a heavy cart slowly along. Ask it to gallop, and it will answer, "With all my heart! but you must give me a lighter carriage to draw." And now fancy another flying over the ground with a gig behind it. Ask it to exchange the gig for the cart, and it will say, "Yes; but then I shall have to go slowly."

Whereby you see that with the same amount of strength to work with, one has the choice of two things: either of conquering a great resistance slowly, or a slight one quickly.

And it is partly on this account, dear child, that I teach you so gradually; for young heads, fresh to the work, are less easily drawn along than others, and have but a certain amount of strength.

Hitherto all has been clear as the day. Now take your scissors in your left hand; hold the lower ring of the handle firmly between your thumb and closed hand, so that the blade shall remain straight and immovable: then with your other hand cause the upper ring to go up and down, and watch the blade as it moves. The whole of it moves at once, and is put in motion by the same power—viz., your right hand. But the point makes a long circuit in the air, while the hinge end makes only a very little one—indeed, moves almost imperceptibly: and, as you may imagine, a different sort of effort is required from the motive power (your hand) according as resistance is made at the point or at the hinge. The point goes full gallop: it is the horse in the gig; the light work is for him. The hinge moves slowly; it is the cart-horse, and takes the heavy labor.

I hope I have made you understand this, for it explains the cracking of our nut, though you may not suspect it. Move your scissors once more in the same way. Now, you have before you the pattern of the two jaws on one side of your face, from the ear to the nose; the upper one, which never moves (as you may convince yourself by placing a finger on your upper lip when you either speak or eat), and the lower one which goes up and down. Two pairs of scissors set points to points give you the whole jaw. The *incisors* are at the points, they gallop up and down, and are worthless for doing hard work; the *molars* are at the hinges, and move slowly; and if anything tough has to be dealt with, it comes to them as a matter of course; hence they are the nut-crackers. You must own that it is pleasant to reflect thus upon what we are doing every day, and the next time you see a stonemason moving stones of twenty times his own weight with his iron bar, ask your papa to explain to you the principle of the lever. After what I have told you, you will understand it very readily, or at least enough of it to satisfy your mind.

But, besides this power of moving up and down, the lower jaw possesses another less obvious one, by means

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of which it goes from right to left. This is precisely what naughty children make use of when they grind their teeth: not that I mean this remark for you, for I have a better opinion of you than to suppose you do such things. Those who make such bad use of their jaws deserve to lose the power of ever moving them thus, and then they would find themselves sadly at a loss how to chew their bread—for their *molars* would be of but little service to them in such a case; as it is chiefly by this second action of the jaw that the food is pounded. Try to chew a bit of bread by only moving your jaw up and down, and you will soon tire of the attempt.

One word more to complete my description of the teeth: that portion of them which is in the jaw is called the *root;* and the *incisors*, which cannot work hard because, like the gig-horses, they have but little resisting power, possess only small and short roots; whereas the *canines*, whose duty it is to tear the food sideways, would run the risk of being dragged out and left sticking in the substances they are at work upon, if they were not well secured; these, therefore, have roots which go much deeper into the jaw, and in consequence of this they give us more pain than the others when the dentist extracts them: those famous *eye-teeth*, which so terrify people on such occasions, are the *canines* of the upper jaw, and lie, in fact, just below the eye.

The *molars* meanwhile would be in danger of being shaken in the sideway movement, while chewing: so they do as you would do if you were pushed aside. Now you would throw out your feet right and left in order to steady yourself, and thus the molars, which have always two roots, throw them out right and left for the same purpose. Some have three, some four, and they require no less for the business they have to do.

Above the root comes what is called the crown ; that is the part of the tooth which is exposed to the air ; the part which does the work, and which bears the brunt of all the rubbing. Now, however hard it may be, it would soon end in being worn out by all this fun if it were not covered by a still harder substance, which is called *enamel.* The *enamel* which forms the coating of china plates, and which you can easily distinguish by examining a broken plate, will give you a very exact idea of it. It is this enamel which gives the teeth the polish and brilliancy we so much admire, and it is desirable to be very careful of it, not out of vanity, though there is no objection to a little vanity on the subject, but because the enamel is the protector of the teeth, and when that is destroyed, you may say good-bye to the teeth themselves. All acids eat into the enamel, as vinegar or lemon-juice does into marble ; and one of the best means of preserving this protecting armor of the teeth is never to eat the unripe windfalls of fruit, which I have seen unreasonable children pick up in orchards and devour so recklessly. They give sufficient warning, by their acidity, that they are not fit for food, and when this warning is neglected, they take their revenge by corroding the enamel of the teeth ; not to speak of the disturbance which they afterwards cause in the poor stomach.

I said that without this coating of enamel, the teeth would be prematurely worn out, the reason of which is, that the teeth have not the property of growing again, as the nails and hair have. When those little germs of which I spoke when we began to describe the teeth, have finished their work, they perish and fall out, like masons who, when they have built the house, take their departure forever.

But the " forever " wants explanation. For such stern conditions would fall hard on very little children, who, not having come to their reason, cannot be expected to understand the great value of their teeth, and take all the care they need of them. So to them *a second* chance is given.

Your first teeth, the *milk-teeth*, as they are called, count for nothing: they are a kind of specimen, just to serve while you are very young.

When you are approaching what is called the age of reason, (and this word implies a great deal, my dear child,) the real teeth, the teeth which are to serve you for life, begin to whisper among themselves, "Now, here is a little girl who is becoming reasonable, and who will soon, or else never, be fit to take charge of her teeth." No sooner said than done: other masons set to work in other cells, placed under the first set, and as the permanent teeth keep growing and growing, they gradually push out the milk-teeth, which were only keeping their places ready for them till they came.

This is just your case at present, and you now understand your responsibility, and how necessary it is to preserve those good teeth which have placed so generous a confidence in your care of them, and which, once gone, can never be replaced.

You have no loss by the exchange; you had twenty-four at first, you will now have twenty-eight. Twenty-eight, did I say? nay, you will have thirty-two; but the last four will come later still. The last *molars* on each side, above and below, in both jaws, will not make their appearance till you are grown up. They are a fastidious and timid set, and will not run any risks; and they are called *wisdom-teeth*, because they do not appear till we are supposed to have arrived at years of discretion. Some people do not cut them before they are thirty, and you will agree that, if they have not become wise by that time, they have but a very poor chance of ever being so!

There is much more still to be said about the teeth; but I think I have told you quite enough to teach you the importance of these little bony possessions of yours, which children do not always value as they deserve, and whose safety they endanger as carelessly as if they had fresh supplies of them ready in their pockets. If so many skilful contrivances have been devised for enabling us to masticate our food properly, it is clear that this process is not an unimportant one. Those, therefore, who swallow a mouthful after two or three turns, forget that they are thereby forcing the stomach to do the work the teeth have neglected to do, and this is very bad economy, I can assure you. You will see hereafter, when we speak about animals, that by a marvellous compensation of nature, the power of the stomach is always great in proportion to the *in*efficiency of the teeth, and that by the same rule, it is weakest when the jaws are best furnished. Now, no jaw is more completely furnished than the human one; it is clear, then, that it should do its own work and not leave it to be done by those who are less able: and the little girl who, in order to finish her dinner more quickly, shirks the use of her teeth, and sends food, half chewed, into her stomach, is like a man who, having two servants, the one strong and vigorous, the other feeble and delicate, allows the first to dawdle at his ease, and puts all the hard work on the other. He would be very unjust in so doing, would he not? And as injustice always meets with its reward, his work is sure to be badly done.

Now, the work in question consists in reducing what we eat into a sort of pulp or liquid paste, from which the blood extracts at last whatever it requires. But the teeth may bite and tear the materials as they please, they can make nothing of them but a powder, which would never turn into a pulp, if during their labors they were not assisted by an indispensable auxiliary. To make pap for infants what do we add to the bread after it is cut in little bits? Without being a very clever cook, you will know that it is water which is wanted. And thus, to assist us in making pap for the blood, Providence has furnished us with a number of small spongy organs within the mouth, which are always filled with water. These are called *salivary glands.* This water oozes out from them of itself, on the least movement of the jaw, which presses upon the sponges as it goes up and down. The name of this water, as I need scarcely tell you, is *saliva.*

When I call it water, it is not merely from its resemblance; *saliva* is really pure water with a little *albumen* added. Do not be afraid of that word—it is not so alarming as it appears to be. It means simply the substance you know as the *white of egg.* There is also a little soda in the water, which you know is one of the ingredients of which soap is made. And this explains why the saliva becomes frothy, when the cheeks and tongue set it in motion in the mouth while we are talking; just as the whites of egg, or soapy water, become frothy when whipped up or beaten in a basin.

But the albumen and the soda have not been added to the saliva, in our case, merely to make it frothy; that would have been of very little use. They give to the water a greater power to dissolve the food into paste, and thus to begin that series of transformations by which it gradually becomes the fine red blood which shows itself in little drops at the tip of your finger when you have been using your needle awkwardly.

When once minced up by the teeth and moistened by the saliva, the food is reduced to a state of pulp, and having nothing further to do in the mouth, is ready to pass forward. But getting out of the mouth on its journey downwards is not so simple an affair as getting into it by the *front door*, as it did at first. Swallowing is in fact a complicated action, and not to be explained in half a dozen words, and I think we have already chatted enough for to-day. I only wish I may not have tired you out with these interminable teeth! But you may expect something quite new when I begin again.

LETTER VII.

THE THROAT.

You remember a certain door-keeper, or porter, of whom we have already spoken a good deal, who resides in the mouth—the sense of taste, I mean?

Well, it is a porter's business to sweep out the entrance to a house, and you may always recognize him in the courtyard by his broom.

And accordingly our porter too has a broom specially placed at his service, namely, the tongue; and an unrivalled broom it is—for it is self-acting, never wears out, and makes no dust—qualities we cannot succeed in obtaining in any brooms of our own manufacture.

When the time has come for the pounded mouthful (described in the last chapter) to travel forward (the teeth having properly prepared it), the broom begins its work; scouring all along the gums, twisting and turning right and left, backwards and forwards, up and down; picking up the least grains of the pulp which have been manufactured in the mouth; and as the heap increases, it makes itself into a shovel—another accomplishment one would scarcely have expected it to possess. What it gathers together thus, rolls by degrees on its surface into a ball, which at last finds itself fixed between the palate and the tongue in such a manner that it cannot escape; at which moment the tongue presses its tip against the upper front teeth, forms of itself an inclined plane, and—— but stop! we are getting on too fast.

At the back of the mouth, (which is the antechamber, as we said before,) is a sort of lobby, separated from the mouth by a little fleshy tongue*let*, suspended to the palate, exactly like those tapestry curtains which are sometimes hung between two rooms, under which one is enabled to pass, by just lifting them up.

If this lobby led only from the mouth to the stomach, the act of swallowing would be the simplest thing in the world; the tongue would be raised, the pounded ball would glide on, would pass under the curtain, and then good-bye to it. Unfortunately, however, the architect of the house seems to have economized his construction-apparatus here. The lobby serves two purposes; it is the passage from the mouth to the stomach, as well as from the nose to the lungs.

The air we breathe has its two separate doors there—one opening towards the nose, the other towards the lungs; through neither of which is any sort of food allowed to pass. But, as you may imagine, the food itself knows nothing of such spiteful restraints, and it is a matter of perfect indifference to it through which of the doors it passes. Not unlike a good many children who, though they are reasonable creatures, will push their way into places where they have been forbidden to go; and who can expect a pulpy food-ball to be more reasonable than a child? It was necessary, therefore, so to arrange matters that there should be no choice on the subject; that when the food-ball got into the lobby it should find no door open but its own, namely, that which led to the stomach. And that is exactly what is done.

You have not, perhaps, remarked that in the act of swallowing, something rises and contracts itself at the same moment in your throat, producing a kind of internal convulsion which jerks whatever is inside. People do not think about it when they are eating, because it is an involuntary action, and their attention is otherwise engaged.

But try to swallow when there is nothing in your mouth, and you will perceive what I mean at once.

Now, imagine our lobby at the back of the throat as a small closet, with a doorway in its wall, half-way up, the doorway being closed by a curtain. In the ceiling is a hole, which leads to the nose ; in the floor two large tubes open out ; the front one leading to the lungs, the one behind, to the stomach.

Now swallow, and I will tell you what happens. The curtain rises up and clings to the ceiling, and thus the passage to the nose is stopped up. The lung-tube rises along the wall, and hides itself under the door, contracting itself, and making itself quite small, as if it wished to leave plenty of room for the mouthful of food which is about to pass over it ; and, for still greater security, at the very moment it rises, it pushes against a small trap-door which shuts up its mouth. No other road remains, therefore, but through the tube which leads to the stomach ; the pulpy mouthful drops straight therein, without risk of mistake, and when it is once there, everything readjusts itself as before.

These are very ingenious contrivances, and I will venture to say that if we would but study the wonders of the marvellous and varied machinery which is constantly at work in our behalf within us, we should be much better employed than in learning things from which no practical good can be derived. Moreover, we should be ashamed to trust, like the lower animals, only to our instinct, (which, after all, is much less developed in us than in them,) for blindly escaping the thousand chances of destruction that beset a structure so fragile and delicate in its contrivances as the human body. Besides, it is not only our own machinery that is entrusted to us, we are liable to be responsible for that of others, whose development it is our duty to guard and watch; and how can we do this with a safe conscience, if we are ignorant of the construction, the action, the laws of all sorts which the great Artificer has, so to speak, made use of in forming our bodies?

When you, in your turn, are a mother, you dear little rogue, who sit there opening wide your bright eyes, and not comprehending a word of what I am saying, you will be glad that you were taught when you were little, how your own little girl ought to be managed. You will find a hundred opportunities of making good use, in her behalf, of what you and I are learning together, and in the meantime there is no reason why you should not yourself profit by the knowledge you have gained.

I am quite sure, for instance, that in repeating to your child the simple rule of politeness, with which everybody is acquainted, "*Never talk when you are eating*," you will be very careful to add, "*and especially when you are swallowing*," for reasons I am about to detail.

When we want to speak we have to drive the air from the lungs into the mouth, and our words are sounds produced by this air as it passes through. This is the reason why I advise you to go on gently, and make the proper stops in reading aloud: to *take breath*, in fact, as it is called; otherwise, breath would all at once fail you, and you would be obliged to stop short in the middle of a sentence and wait like a simpleton till you had refilled the lungs with air by breathing. It was for this purpose, also, and not for mere economy's sake, as you may have thought, that the little cross-road of four doors has been placed at the back of the mouth, enabling it to communicate at pleasure with either the lungs or the stomach. It is a dangerous passage for food-parcels making their way to the stomach; but if you could substitute for it, as it may have occurred to you to do lately, a simple tube going directly to the stomach,—behold! you would find yourself dumb;—a serious misfortune, eh? for a little girl! But come, I am quizzing too much, so console yourself. I know many grown-up people who would be at least as sorry as yourself.

To return to our subject. We have said that, in order to guard against accidents, the lung-tube is closed at the moment we are about to swallow. But if by any unlucky chance the air is coming up from the lungs at the same moment, it must have a free passage. Its tube cannot help returning to its place; the little trap-door which shuts up the opening opens whether or no, and then adieu to all the precautions of good Mother Nature! The mouthful when it drops, falls outside of its proper tube—that is to say, into the other, which is exactly in front of it, and we find that we have *swallowed the wrong way.*

You know what happens in such a case. You cough and cough till you are torn to pieces, till you grow scarlet, or even blue in the face; till you lose your breath; till your body trembles; till your eyes start out of their sockets. Let who will be there, there is no resource but to hide your face in your handkerchief. The tube, which was only made for the passage of air, on finding an intruder forcing an entrance, does its utmost to drive it back through the door. Then the lungs, which would be destroyed by its getting to them, come to the assistance of the faithful servant who is struggling for their protection: they agitate themselves violently, and send forth gusts of air which drive all before them. Thence arises the cough, and by this means at last the enemy is thrust out of the mouth, like dust before the wind. And it is only when the passages are cleared that the storm subsides. But the commotion is no laughing matter, I assure you; for if one had swallowed a little *too far* the wrong way, or if the substance swallowed had been too heavy for the air-tube, aided by the lungs, to eject within a certain time, death would have ensued: instances of which are by no means unknown. Nature does nothing in vain; this is no case of a man frightened by a mouse. When you find your whole being concentrating its efforts to one point, and betraying such distress, at an accident apparently so trifling, you may be sure there is danger, and real danger too; and if you doubt it, that makes no difference—happily for you.

Now you have learned why little girls should not attempt to talk and swallow at the same time, and, I may add, still less laugh; for laughing is a kind of somersault, performed by the lungs, and is always accompanied by the ejectment of a great deal more breath than is necessary in speaking, so that the jerks it occasions derange still more the wise provisions made to protect life whenever we swallow anything, and therefore we are more apt to swallow the wrong way while laughing than while speaking.

Need I say that we ought equally to guard against making others laugh or talk; or exciting, or frightening them, while they are swallowing; in short, avoid doing anything to create a sudden shock which might suddenly force the air out of their lungs, and cause them in the same manner to swallow the wrong way? Politeness requires this from us, and what I have now said will fix the lesson still more strongly on your mind. What would become of you if you were to see a person die in your presence in consequence of some foolish joke, however apparently innocent?

Not to conclude with so painful a picture, I will, before we part, give you the right names of the *curtain*, the *lobby* or *closet*, and the *tubes* of which we have been speaking.

The curtain is called the *Soft Palate*.

The lobby, the *Pharynx*.

The tube which leads to the stomach, the *Œsophagus*.

The tube leading to the lungs, the *Larynx*.

The opening of this tube is the *Glottis*, and the little trap-door which closes it when one swallows, is the *Epiglottis*.

You must excuse my attempting to explain the meanings of all these names; it would take me too long to do so. After all, the mere names are nothing. If I have succeeded in making you understand how all the different parts act, you may call them what you like.

Here we will rest. We are now on our way to where we shall see the large apartments, and be introduced to the master, that head of the house, whom no one can approach without so many ceremonies.

LETTER VIII.

THE STOMACH.

ONCE in the *œsophagus* (you remember this is the name of the tube which leads to the stomach), the mouthful of food has nothing to do but to proceed on its way. All along this tube there is a succession of small elastic rings,* which contract behind the food to force it forward, and widen before it to give it free passage. They thus propel it forward, one after another, till it reaches the entrance to the stomach, into which the last ring pushes it, closing upon it at the same time.

Have you ever observed a worm or a leech in motion? You see a successive swelling up of the whole surface of its body, as the creature gradually pushes forward, just as if there was something in its inside rolling along from the tail to the head. Such is precisely the appearance which the *œsophagus* would present to you, as the food passes down it, if you had the opportunity of seeing it in action; and this has been called *the vermicular movement*, in consequence of its resemblance to the movement of a worm.

Here I wish to draw your attention to the very important fact, that this movement is in one respect of a quite different nature from that of your thumb when you take hold of a bit of bread, or that of your jaw when you bite with your teeth, or of your tongue, &c., when you swallow. All these actions belong to yourself, to a certain extent; they are voluntary, and under your own guidance; that is, you may perform them or not, as you choose. There is a constant connexion between you and them, and you knew what I meant at once as I named each of them in succession. But in speaking of this other movement we enter upon another world, of which you know nothing. Here is the black hole of which I spoke. The little rings of the *œsophagus* perform their work by themselves, and you have no power in the matter. Not only do they move independently of you, but were you to take it into your head to stop them, it would be about as wise a proceeding as if you were to talk to them. We will speak hereafter, in another place, of these impertinent servants, who do not recognise your authority, and with whom we shall have constantly to do, throughout what remains to be said on the subject of eating. The truth is, your body is like a little kingdom, of which you have to be the queen, but queen of the frontiers only. The arms, the legs, the lips, the eyelids, all the exterior parts, are your very humble servants; at your slightest bidding they move or keep still: your will is their law. But in the interior you are quite unknown. There, there is a little republic to itself, ruling itself independently of your orders, which it would laugh at, if you attempted to issue them.

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* Properly, *contractile circular fibres.*

This republic, to make use of another metaphor, is the kitchen of the body. It is there they make blood, as they know how; putting it to all sorts of uses for your advantage, it is true, but without your consent. You are in the position of the lady of a house whose servants have shut the door of the kitchen in her face that they may carry on their business after their own fashion, leaving only the housemaid and coachman at her command. It may be humiliating, perhaps, to be thus only partially mistress at home; but what can you do, my little demi-queen? I will tell you: make up your mind to govern the subjects under your orders as wisely as possible; and, as to the rest, be content with the only resource left you: viz., that of looking in at the window of the kitchen to see what goes on there!

The stomach is the head cook: the president of the internal republic. He has charge of the stoves; the whole weight of affairs is on his hands, and he provides for the interests of all. Æsop taught us this, long ago, in his fable of "The Belly and Members."* It is a very good fable, and was wisely appealed to once by a Roman Consul to appease a disturbance in the State. But the application was not quite fair in one respect; and since I have started the subject, I will satisfy myself by explaining to you where it was wrong. The time will not be wasted, for this fable has furnished information to a great many people about the economy of their insides, and possibly to you; and I should like you to know the exact truth of all the particulars alluded to. Whether Æsop understood them all, I cannot pretend to say; but the application by the old Roman to the quarrel between the big-wig senators and the people was on one point decidedly unjust; for there was, as far as facts are concerned, something to be said on behalf of the stomach, which Consul Menenius seems not to have thought of.

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* La Fontaine's translation is quoted in the French original, where the name of the fable is "*Messer Gaster,*" a more correct title than our own. *Gaster* is a Greek word signifying stomach; and it is strictly *the stomach* which is *meant* in the fable. From this comes, too, the medical term *gastritis,* the name of a disease of the stomach —Tr.

When you come to this part of the Roman history you will learn that the Roman Senate was a large and fat stomach, which did, it is true, furnish good nourishment to the other members of the State, but kept the best share for itself. We may say this now without risk of offence, it having been dead for so long a time. Our stomach is the leanest, slightest, frailest part of our body. It is master in the sense in which it is said in the Gospel, "Let him that is first among you be the servant of the others." It receives everything, but it gives everything back, and keeps nothing, or almost nothing, for itself. Between ourselves, Consul Menenius, the advocate of the Senate, had no business to talk to the poor wretches at Rome of any comparison between their government and so careful an administrator of the public good as a human stomach. He should have taken his subject of comparison from the families of geese or ducks—animals which have no teeth. These have strong, well-grown stomachs — true Roman senators — whose stoutness is in proportion to the work given them to do. But man provides his with work already prepared by chewing, supposing him to have had the sense to chew it, of course. It was not from a comparison with man, therefore, that Menenius ought to have got his boasted apologue, which was but a poor jest on the subject.

You did not expect, my dear, to come in for a lesson on Roman History in a discussion on the stomach. But the study of nature is connected with everything else, though without appearing to be so, and I was not sorry to give you, incidentally, this proof of the unexpected light which it throws, as we go along, upon a thousand questions which appear perfectly foreign to it. Look, for example, at this old fable cited by Menenius. For the two thousand years and upwards that it has been in circulation, troops of historians, poets, orators, and writers of all kinds, have passed it forward from one to the other, without having troubled themselves to investigate the laws of nature in connection with the stomach; therefore, not one, that I am aware of, has observed this small error, so trifling in appearance, so important in reality, which nevertheless is obvious to the first young naturalist who thinks the matter over.

But enough of the Romans. Let us return to our master—the head cook, if you choose to call him so.

I was telling you just now that he managed the stoves, and you may have thought that I was merely using similes, as I am apt to do. But not so: it is quite true that he cooks; and so now tell me, if you can, whence he gets his fire to cook with, or rather, to speak more correctly, who gives it to him?

Now you are quite puzzled, so I must help you out.

In the mansion we were talking about some time ago, to whom would any one who wanted to light a fire, apply for wood?

I think you can answer this yourself, for you cannot have forgotten our famous steward, who gives everything to everybody. But, you will wonder, I dare say, how the blood can carry wood in his pockets.

Wood? Ay, and real wood too, as we shall soon see: but it is not wood we are talking about now. The blood has something more to the purpose than wood in his pockets, for he has heat ready made. So when the stomach wishes to set to work, it appeals to the blood, which comes running from all parts of the body, and heats it so effectually that everything within is really and actually cooked. This is why one feels a sort of slight shudder down the back when the stomach has a great deal to do at once, for the blood being called for in a hurry, comes rushing along in great gushes, and carries with it the heat from the other parts of the body.

It is for this reason, too, that it is so dangerous to bathe when the stomach is at work cooking, because the cold of the water drives suddenly back all the blood which has accumulated around the little saucepan, and this causes such a shock in the body that people often die of it.

Do not ask me, to-day, where this heat of the blood comes from; we will speak of that hereafter. But I may tell you at once that our dear steward is not a bit cleverer in this matter than other people, and obtains his heat, like the humblest mortal, by burning his wood. Do not puzzle yourself to find out how. Enough that he burns it as we do, and by a similar process.

Well, in one way or another, the master cook has his fire at command. You know also, already, what it is he has to get cooked; namely, the pulpy stew, which has begun in the mouth by chewing, and which it is his business now to finish perfectly. Now see what a cook does who has got her stew over the fire. She turns and turns it again and again, and shakes the saucepan from time to time, that the ingredients may be more thoroughly mixed up together; and this is precisely what is done by the stomach; for all the time that the cooking is going on, he swells and contracts himself alternately, after the fashion of those rings of the *œsophagus* we were talking about, tossing and tumbling the food from one side to another, so as to knead it, as it were.

Again, the cook adds water to her stew from time to time to keep it moist; and so the stomach pours constantly upon his stew a liquid, which contains a great deal of water, and which flows in from a quantity of little holes, sunk in his delicate coats.

What more?

The cook puts in a little salt: and this the stomach takes care not to forget either, for he is a cook who understands his business. In the liquid of which I am speaking, there is, if not exactly salt as one sees it at table, at all events the most active part of salt, that which possesses in the highest degree the property of reducing everything we eat to a paste; and this is the real reason why we find all food so insipid which has not been seasoned with salt. As salt contains a principle essential to the work to be done by the stomach, some method had to be devised to induce us to provide him with it, and this method the porter up above has hit upon. He makes a face if we offer him anything without a little salt on it, as much as to say—"How can you expect them to cook you properly down below, my good friend, if you don't bring them proper materials?"

Upon which hint men have always acted from the beginning; and as far as we can trace history back, we find them mixing salt with their food, though without knowing the real reason why. It is the same, too, with the lower animals. They know nothing of the matter either, but this does not prevent their having a natural relish for salt, as any one will tell you who has the charge of cattle; for their stomachs require for their cooking the very same seasoning as our own, and therefore their porter above has received the same orders.

Salt is not the only thing, however, that exists in that liquid in the stomach. Learned men, after making minute researches, have found in it another equally powerful material, which is also found in milk. Therefore cheese, which contains this material as well as salt, is quite in its place at the end of dinner. It furnishes reinforcements for the stomach in cooking, and this is why you so often hear people say that a little cheese helps the digestion.

The *digestion!* Yes, that is the word I ought to have begun with. It is the real name of all this cooking; an operation after which I would defy you to recognise the nice little cakes you have eaten, any better than your mamma can trace her pretty rosy-cheeked apples in the jelly which she left on the fire two hours ago. The stomach, as you see, is very busy quite as long a time as that. and if we have to be very careful (as I pointed out before) not to disturb him too suddenly in his work after dinner, it is also important that we should not, while at dinner, give him more work to do than he is capable of doing. Although he is the master, he is but a puny fellow, as I have already pointed out; nevertheless, he works conscientiously, because he knows that the life of the whole body depends upon his exertions. Some people even say that in spite of his leanness he strips himself, at each digestion, of his interior skin, which he sacrifices to his work, and the fragments of which tend to increase and improve the stew which is entrusted to his care. Think of this, my dear, whenever a greedy fit comes over you, and recollect that such a disinterested public functionary deserves some consideration. Besides, there is serious danger, quite apart from any question of injustice, in overwhelming him with work. If your legs are wearied out, you have it in your power to lie in bed. If your arm is in pain, you can keep it at rest. But your stomach is like those poor people who have to support their families by the labor of each day. He, too, labors for others: he has no right to rest, no right to be ill, therefore; and when he begins to fail, woe betide you—you will have enough of it.

Children who have learnt nothing may laugh at all this, but you, my dear, are beginning to know something, and "science constrains," *i.e.* it has its claims and requirements. It requires you, to-day, not to be greedy, to-morrow, something else, and so on, continually, until you have become quite reasonable and wise. I am sorry for you if this vexes you, but it was your own wish to learn, and *science constrains.* Indeed, I will whisper to you in confidence that this is the best excuse people who are unwilling to learn have to offer for refusing. They do not know what learning may lead to, and what a pity it would be if they could no longer be greedy, or ill-natured, or selfish. What would become of us all in such a case?

LETTER IX.

THE STOMACH—(*continued*).

We made a very long story of the stomach last time, my dear child; and, after all, I see that there was one thing I forgot to tell you—viz., what it is like.

Have you ever seen a bagpiper, I wonder? A man who carries under his arm a kind of large dark brown bag, which he fills with air by blowing into it, and out of which he presently forces the same air into a musical pipe by pressing it gently with his elbow. If you never saw such a thing, it is a pity; first, because the bagpipe was the national instrument of our ancestors the Gauls, and is religiously preserved as such by the Scotch Highlanders and the peasants of Brittany—(two remnants of that illustrious race, whose history I recommend to your careful perusal some day); secondly, and it is this fact which has the greatest interest for us just now, because that large bag, which is the principal part of the instrument, gives you a very exact idea of your stomach; for in fact it really and truly *is* a stomach itself, and moreover, the stomach of an animal whose interior formation resembles yours very, very much.

And who do you suppose is this audacious animal, which presumes to have an inside so like that of a pretty little girl? Really, I am half ashamed to name him, for fear you should be angry with me for doing so. It is—it is the pig! The resemblance is not exactly a flattering one to you, perhaps, but we are all alike, and it would be worse than foolish to grumble at being created as we are. Moreover, there is one difference; the pig, who thinks of nothing but eating, has a very much larger stomach than we have, which is some consolation, at any rate.

Place the palm of your right hand on what is called the pit of the stomach, turning the ends of the fingers towards the heart; your hand will nearly cover the space usually occupied by the stomach, and you may figure it to yourself as a rounded and elongated bag, bigger above than below, making a very decided bend inside as it descends from the heart downward; something like one of those long French pears, called "Bon-chrétiens," if it were bent in the middle, and the big end of it were placed next the heart. As for the exact size of the bag, there is no telling it, for it depends upon circumstances. It is a very convenient bag in that respect; just such a one as you would like to have in your frock for a pocket; only there would be a danger of your being tempted to put too many things into it. For as you fill it, it expands, and enlarges itself like an indian-rubber ball, which, though only the size of an egg to begin with, becomes as big as your head if you blow hard into it. Then, as it gets empty, it recovers itself, diminishing gradually in size in plait-like contractions.

When people remain too long without eating, they have, as they say, twinges in the stomach. This is because the stomach, becoming by degrees quite empty, and contracting more and more, the surrounding parts which were sustained by it, lose their support, and strain at their ligaments, which now have all the weight to bear. Careless people, who do not think of such things, are reminded by the twinging pains that it is time to eat, just as a careless servant is called to order by the bell of which his master has pulled the string.

In your case, my dear child, such warnings are soon attended to, and you have not always even to wait till they come. But there are hundreds of miserable beings who are warned to no purpose, who cannot obey the master when he calls for his rations, because they have nothing to give him ; and when this forced disobedience lasts too long, they end by dying of it. In cases like these, when human beings thus cruelly perish, the stomach is found to be contracted till it is scarcely bigger than one's finger.

On the other hand, a man once died suffocated from excess of food, after one of those great public dinners, which last four, six, or more hours—one can scarcely say correctly how long—and the doctors who examined him found his stomach so prodigiously enlarged that it alone occupied more than one-half of his inside.

As you perceive, therefore, the stomach has, properly speaking, no fixed size. Its size depends upon what there is in it. It is like those men whose manners go up and down with their fortunes ; who seem very grand people when their pockets are well filled, but become very small ones when their purses are empty. There is, nevertheless, this difference between them, that such men are fools, because they are men, and not *bags ;* whereas the stomach is a sensible bag, fulfilling with intelligence the duties of its character as a bag. It is very fortunate for us that it is ready to change its size, according to the caprices of our appetite ; and dressmakers would do well if they could get a hint from it how to improve their style of pockets, which certainly cannot have cost their inventors any very great effort of imagination !

The way in which this extraordinary pocket empties itself is not less curious than the rest. As long as digestion is going on, the stomach is firmly closed at each end; at the upper one by the last ring of the *œsophagus*, and at the lower by another ring of the same kind, only stronger; the watchful guardian of the passage which leads to the intestines. This ring is called the *pylorus*.

For once, here is a name which agrees with our method of describing the human machine, and I have much pleasure in translating it to you, although it is a Greek word. *Pylorus* is the Greek for a porter; and our ring is indeed a porter like the one of which we have already said so much, and which I called last time the *porter up above*, in anticipation of his colleague below.

The porter up above presides at the entrance; the one below at the exit, and both for the same purpose, namely, to *taste*.*

It may well astonish you, that you should have in your inside a taster who is not accountable to you; who experiences sensations of which you know nothing, and cannot even form an idea. Yet thus it is. The *pylorus* actually tastes the paste which is in the stomach, and if it is not to his taste, that is to say, if the work of digestion has not sufficiently transformed it for use, he keeps the door relentlessly closed.

The porter up above has a thousand different tastes. He makes his bow to meringues, and admits wings of chickens. Fries, roasts, stews, things tender or crisp, sweet and salt, oily, greasy, or sour; among all kinds he has friends whom he welcomes in succession; and it is well for us that he does so, for we share in all his pleasures.

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* It would be absurd to say so in the common acceptation of the term; but according to No. 1 of Mr. Mayo's "Classification of the impressions produced by substances taken into the fauces," viz., "*Where sensations of* touch *alone are produced, as by rock-crystal, sapphire, or ice*," the word *taste* may be applied to the discriminating faculty of the *Pylorus*.—Tr.

The porter below, who works for himself alone, obscure and unknown down in his black hole, the porter below, I say, has but one taste, knows but one friend–a gray-looking paste, semi-liquid, with a very peculiar unsavoury smell, disagreeable enough to any one but himself, which is called the *chyme*, I scarcely know why, but it is what everything one eats turns into, without exception, be it delicate or coarse by nature. The great lord's truffle-stuffed pullet makes, as nearly as possible the same *chyme* as the charcoal-burner's black bread; and though the palate of the former may be better treated than that of the latter, the *pylori* can enjoy but one and the selfsame sauce. Equality is soon restored in this case, therefore, as you see.

To be free to pass through then, the contents of the stomach must be reduced to the condition of *chyme*, the only substance which finds favor with the *pylorus:* and as, in the endless varieties of food which go to form our nutriment, some sorts turn into *chyme* much more quickly than others, it follows, that by the aid of its discriminating tact (which is not easy to elude) the *pylorus* allows some to pass, while it turns back others, until all in succession are converted into chyme. For example, in the case of a mouthful of bread and meat swallowed at once, the bread passes away on its travels long before the meat has done dancing attendance in the stomach, awaiting that transformation without which the *pylorus* will never allow it to slip through.

This ought to make you seriously reflect on the danger of carelessly swallowing things which, by their nature, are not susceptible of being converted into *chyme*, particularly if they are too large to hide in the paste, as a cherry-stone will sometimes do, so mixed up with other food as to pass unperceived by the *pylorus*, over whose decisions we have no control, remember. It bangs the door to, be assured, in the very face of anything obnoxious without hesitation, and the poor stomach would find itself condemned to retain them for an indefinite period, unless by dint of prayers and supplications they should contrive to soften the stern guardian, who may at last get accustomed to their approach, and, perhaps, in a weak moment, allow them to pass as contraband goods ; like a custom-house officer on a foreign frontier who will occasionally shut his eyes to a country friend's packet of tobacco. But the poor stomach has had to suffer a martyrdom meantime, while the dispute was pending, and before the intruder has been winked at by the porter.

I shall remember all my life the history of a peach-stone, which was related to me in 1831. I was at the time a youngster at the Stanislaus College, and (aided perhaps by the Revolution of July, which had recently occurred), it was just then discovered to be a proper thing to set about teaching the laws of nature to children. Consequently, for the first time in the history of schools, a professor of natural history was added to the instructors of Latin and Greek. I leave you to judge how we opened our ears to his lessons. When we arrived in the course of our new studies at the *pylorus*, of which we had none of us ever heard before, our professor, in warning us, as I have done you, of the dangers of imprudent gluttony, related, as an instance, the case of a lady who had inadvertently swallowed a peach-stone. For two years she suffered agonies in her stomach without any cessation or relief. The luckless peach-stone, repelled by the walls of the stomach, which its very touch irritated, was incessantly thrown against the entrance of the *pylorus*, but in vain. As to turning itself into *chyme*, such a thing was not to be thought of, it was far too hard a substance for that. Round and round it went, causing in its relentless course such renewed suffering to the poor patient, that she was visibly sinking from day to day.

The doctors, finding all their treatment of no avail, began to despair of her life, when one fine day she was suddenly, and as if by enchantment, relieved of her tormentor. The peach-stone had bribed the porter, with whom, in the course of the two years, it had scraped up a sort of friendship. It had cleared the terrible barrier, had been allowed to slip out, and the lady was saved; but it was only just in time.

I do not know, my dear, that this story, which is certainly well calculated to cure you of any fancy for swallowing peach-stones, will make as much impression on you as it did on me five-and-twenty years ago. The idea of telling it to you occurred to me quite by chance. It has carried me back to the time when, as is now the case with you, the mysteries which lie hidden in our internal organization were beginning to be revealed to my mind; and you will one day know with what delight one recalls the remembrance of these first dawnings of the intellectual life—that delightful infancy of the growing mind—more rich in recollections, and more interesting a thousand fold than the infancy of the body. I have allowed myself the little treat of this episode, and if I have had the good fortune to amuse you at all during our progress, you must not cavil at this piece of self-indulgence.

And now we have done just what the peach-stone did; we, too, have passed the barrier, and are out of the stomach, but still we have not yet come to the end of our tale.

LETTER X.

THE INTESTINAL CANAL.

I VENTURE to hope, my dear child, that more and more light is dawning upon your mind, as we gradually proceed on our little journey. You must by this time have some idea how the food, which has been masticated and softened in the mouth, cooked, kneaded, and decomposed in the stomach, and transformed into a soft, semi-transparent kind of paste, will soon be ready to mix with the blood, in order to repair the waste that the life-stream is continually undergoing in its ceaseless course through all parts of the body.

You have perhaps thought it a sad degradation for a truffle-stuffed fowl to turn to *chyme.* But when you consider that by this means it becomes part and parcel of a human body, the change is not to be despised. It was necessary, to begin with, that materials destined to the honor of being incorporated into our frame, should break the links which bound them to the condition of fowl and vegetable, and thus be free to engage in new relations; just as a man who wishes to be naturalized in a new country must first break the ties which hold him to the old one. Those articles of food we were speaking of lately, which are so stiff and ceremonious, and want so much coaxing before they change into *chyme,* which, moreover, we call *indigestible* because they tire the stomach so much more than the rest, are merely those whose component parts being held together by more solid ties than usual, continue obstinately in the same state as at first, and will not consent to that dissolution which is the first condition of their glorious transformation.

Moreover, the transformation which has been described to you now, you will henceforth meet with everywhere; wherever, that is to say, and as far as, you choose to pursue the study of nature. God works by one grand and simple rule so far as we can discover. He destroys to reconstruct, builds up what is to be, out of the ruins of what has been, creates life by death, if I may so express myself, and thus, what takes place in our stomachs on a small scale goes on on a large one in the universe.

Social communities, like everything else, are subject to this universal law, and it is not always an advantage to them when they refuse to be digested in the great stomach of the age!

While we are on this subject, and to show you how wonderfully this little history of eating, told in this familiar style, applies right and left, let us reflect on the causes which have produced a great and mighty nation in one country (as in France), while in another (as in Germany), a far more numerous and even more intellectual population has failed to rise to anything like the same distinction. The explanation is not difficult. In the one case, the petty tribes among which the land was originally divided consented to mix, and dissolve, and be digested as it were together, in order to revive again for a more glorious career; while in the other, the aboriginal societies have adhered stiffly to their distinctive characters, and failing to submit to the regenerating process, cling together in indigested portions, rather than assimilate into one great whole.

However, we must return to the *pylorus* or we shall be getting into a difficulty! What I am now going to offer you though, is rather hard of digestion, but it will not do to provide sweet pastry only for your brain; it will be more wholesome for it to have something a little more solid to bite at from time to time.

The *pylorus*, then, as has been shown, makes way for all sorts of aliments when they have been converted into *chyme; i. e.*, when they have lost their original form and individuality. They are dead to their first life, therefore; now the question is, how are they to be revived into the new one?

Behind the *pylorus* extends a long conduit or tube—so long as to be sometimes seven times the length of the whole body, but doubled up backwards and forwards a number of times, so as to form a large bundle, which fills the whole cavity of the belly—or as we also call it, the *abdomen*. This bundle or packet is known to everybody as *the intestines*, and it is divided into two portions: the *small intestine*—that is, the slenderer, finer portion which begins at the *pylorus*, and forms all the doublings of the packet, and the *large intestine*, which is shorter and thicker also, as its name implies, and keeps to some extent separate, though it is in reality only a continuation of the other. This starts at the base of the *abdomen*, near the right side, goes up in a straight line to the height of the stomach, below which it passes, making a large bend in front of the small intestine; after which it descends on the left side to the lower part of the trunk, where it terminates.

You will perhaps inquire how the *chyme* continues to make its way through all these manifold twists of the intestines; but do not trouble yourself; it has only to let itself go. That *vermicular movement* which we noticed in the *œsophagus* and in the *stomach* is found here also. It reigns, so to speak, from one end of our internal eating-machine to the other; which eating-machine, by the way, we will now call by its proper scientific name—*the intestinal canal;* and it is by that movement the food is carried forward from the first moment it leaves the mouth, and helped through all its journeyings, till it reaches the termination of the large intestine.

If your body were made of glass, so that you could look through it to watch the intestine at work, it would appear to you like an enormous worm coiled up into a bundle, heaving and moving with all its rings at once. You never suspected there was such a movement within you; yet it has been going on there continually ever since you were born, and will not cease till you die. Your internal machinery never goes to sleep, not even when you are sleeping yourself. It is a workshop in constant operation, providing night and day for your necessities; and in this respect the inner man sets a first-rate example to the outer one! You will recollect what I said to you the other day about the internal republic, and the provinces which are under your sole government. It would be very disgraceful for the kingdom to be doing nothing while the republic is working so hard; and a queen who understands her office will make it a point of honor to banish idleness from her household; in the houses of her neighbors this word is unknown.

The *chyme* once launched into this moving tube, is in no danger of remaining stationary there; the fear is, of its passing on too quickly, as you will soon see. But this danger has been provided against. Along the whole course of its journey, though chiefly at the commencement, it encounters at intervals certain elastic fleshy *valves* which interrupt its progress, and do not allow it to pass till it has accumulated in sufficient force to push them before it, and so escape. In consequence of which it is always being checked in its advance; and during these stoppages a most important work goes on upon it at leisure.

You must understand first, that the substances of which our food is composed, and which are afterwards decomposed in the stomach, are not all invited to enter the blood. Our aliments are something like the stones which the gold-seekers of California reduce to powder in order to extract therefrom the hidden particles of gold they contain. The gold of our food is that portion of it which the blood is able to appropriate to his own advantage; the rest he rejects as refuse. And this explains why a small slice of meat nourishes you more than a whole plateful of salad. Meat is a stone absolutely full of gold, while the salad has only a few veins of it here and there, and by far the greater part of the material it sends to the intestines, has, in consequence, to be thrown away.

Now it is in the first portion of the small intestine, the part known by the Latin name *duodenum*, which signifies twelve (because it is about the length of twelve finger-breadths), that the division takes place between the parts which go to nourish the blood, and those which are useless refuse. It is an important operation as you may suppose, and were the *chyme* to pass rapidly through the small intestine the gold would run the risk of being carried off with the refuse.

After the delay in the stomach, the food-substances make another halt in the *duodenum*, which, being very thin and slender, would have great difficulty in containing them at the time of their grand entry, an hour or two after a meal, were it not that it possesses the property of expanding itself to such an extent, that it swells out on grand occasions to the usual size of the stomach itself, so that it has sometimes been considered as a second stomach. And no doubt the operation which takes place in it gives it a claim to the appellation, for thereby the finishing stroke is put to the work previously begun in the stomach, and one may fairly say that, but for this last touch, very little would be accomplished at all.

Above the *duodenum*, and hid behind the stomach, is a kind of sponge, similar in nature to those we have already observed in the mouth. To this has been given the somewhat ridiculous name of *pancreas;* I call it ridiculous because it is derived from two Greek words which signify *all flesh;* whereas the *pancreas*, which is a sponge of the same description as the salivary glands, presents the appearance of a grayish granulous mass which is not fleshy at all. Whatever be its name, however, our sponge communicates with the *duodenum* through a small tube, by means of which it pours into the *chyme*, as it accumulates, a copious supply of a fluid exactly like the *saliva* of the mouth.

Just by the place where the tube from the *pancreas* empties itself into the *duodenum*, another tube arrives bringing also a fluid, but of a different sort. This last comes from the liver, where there is a manufactory of *bile*—an unpleasant yellowish-green liquid, the name of which you have no doubt heard before, and which plays a very important part in the transformation of the aliments.

These new agents, the bile and the liver, are far too important to be passed over in a few words; I reserve them, therefore, for my next letter. Meantime, not to leave you longer in suspense, I may say that the separation between the gold and the refuse in the *chyme* takes place as soon as the latter has received the two liquids furnished by the liver and the *pancreas*. If you ask in what manner the division is accomplished, I confess, to my shame, that I am not able to explain it! What takes place there is a chemical process, and hereafter I shall have occasion to explain the meaning of that phrase. But the Great Chemist has not in this instance seen fit to divulge to man the secret of the work.

Indeed, you must prepare yourself beforehand, my dear child, to meet with many other mysteries besides this, if we pursue to the end our study of this flesh and bone which constitute the body of man. And here I recall what Camille Desmoulins is reported to have said about St. Just, viz., that he carried his head as high as if it were a consecrated Host.* You will read about these two men by-and-by in history. Meantime I will not bid you do exactly the same as St. Just, because you would be laughed at; but in one point of view he was not altogether wrong. The human body is, in very truth, a temple in which the Deity may be said to reside, not inactively, not veiling his presence, but living and moving unceasingly, watching on our behalf over the mysterious accomplishment of the everlasting laws which equally guide the *chyme* in its workings through our frames, and direct the sun in its course through the heavens. We mortals eat, but it is God who brings nourishment out of our food.

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* The young Protestant reader who has never lived in a Catholic country, will perhaps need to be told, that what is here called Consecrated Host, is the sacramental wafer, or communion bread of the church. In French called *hostie*, in Italian, *ostia*.

In all their religious processions, which are very frequent, the host is carried by the priest highest in authority, in a glass box placed on a staff about four feet long, which he holds before him and so far elevated that he has to look up to it. Over his head a richly embroidered canopy of satin is always carried by several men; and while these are passing, all good Catholics uncover the head and bend the knee, wherever they may be.

It is the custom also for the priest to be called to administer the sacrament to any one about to die, on which occasion he always walks under this canopy, dressed in his priestly robes, carrying the host and preceded by some boys, ringing a bell, when the same ceremony is observed. In passing a regiment or company of soldiers, the column is halted, wheeled into line, and with arms presented, the whole line, officers and men, kneel before it, and the priest usually turns and offers a benediction. When he goes in the evening to the house of the dying, it is customary for the people to go out upon the balconies with lighted lamps and kneel while the host is being carried by.

LETTER XI.

THE LIVER.

I FEAR you will be getting a little weary, my dear, of dwelling so long on this intestinal tube, where things which looked so well on one's plate become so transformed that they cannot be recognized, and where there is nothing to talk about but *chyme*, and *bile*, and the *pancreas*, and all sorts of things neither pleasant to the eye nor agreeable to the ear.

But what is to be done? It is always the same story with useful things. The people by whose labor you live in this world, are by no means the handsomest to look at, and so it is in the little world we carry about in our bodies.

Never mind! Keep up your heart. We are getting to the end. We shall very soon be following the nourishing portion of our food, on its journey to the blood, and you will find yourself in new scenes.

First, though, let us say a few words about the liver—the bile-manufacturer; and to begin with, I will describe the place he occupies in our interior.

The interior of the human body is divided into two large compartments, placed one above the other; the *chest* and the *abdomen*. These are two distinct apartments, each containing its own particular class of tenants: the upper one being occupied by the heart and the lungs (the respective offices of which I will presently explain to you); while in the lower are the stomach, the intestines, and all the other machinery which assists in the process of digestion. These two stories of apartments are separated as those of our houses are, by a floor placed just above the pit of the stomach. This floor is a large thin, flat muscle, stretched like canvas, right across the body; and it is called the *diaphragm*—another hard word! Never mind; but do your best to recollect it, for we shall have great need of it when we come to the lungs. If you had been born in Greece, you would have no difficulty with the word, for it is Greek for *separation.* It means, in fact, a *separating partition*, or, as I called it just now, *a floor.* All this is preparatory to telling you that the liver is hooked to the diaphragm in the abdomen. It is a very large mass and fills up, by itself alone, all the right side of the lower compartment, from the top downwards, to where the bones end which protect the abdomen on each side, and which are called *the short ribs.* Place your hand there, and you will find them without difficulty.

Large as the liver is, it hangs suspended to a mere point of the diaphragm, and shakes about with even the slightest movement of the body. It is partly on this account that many people do not like to sleep lying on the left side, especially after a good dinner, because in this position the liver weighs upon and oppresses the stomach, like a stout gentleman asleep in a coach who falls upon and crushes his companion at every jolt of the vehicle. The liver within you produces, then, the same effect that a cat, lying on the pit of your stomach would do, and the result is that you have the nightmare.

The liver is of a deep-red color. It is an accumulation of excessively minute atoms, which, when united, form a somewhat compact mass, and within each of which there is a little cell, invisible to the naked eye, where an operation of the highest importance to our existence is mysteriously carried on. It appears a very simple one, it is true, yet hitherto it has baffled all attempts at explanation. Listen, however; the subject is well worthy your careful attention, whether it can be explained or not, and we must look back to take it up from the beginning.

I told you about the thousand workmen constantly busied in every part of our bodies, who call on the blood without ceasing for "more, more." You will remember further that it is to enable the blood to supply these constant demands, that we require food.

This being understood, it is not difficult to see why we grow; the difficulty is, rather, to explain why we do not continue to grow.

Consider, for instance, the quantity of food you have eaten during the last year. Picture to yourself all the bread, meat, vegetables, fruits, cakes, &c., piled upon a table. Put a whole year's milk into a large earthenware pan, all the sweetmeats into a large jar, all the soup into a great tureen, and see what a huge heap you will have collected together. Then try to recollect how much you have increased in size with all this nourishment, which has entered your body. But reckoning in this way—even supposing the little workmen had used only a half or even a third of the materials in question, and rejected the rest as refuse—you would have to stoop in order to get in at the door; and as for your papa, whose heap must have been bigger than yours, his case would be desperate indeed; and yet he has not grown at all!

This is very curious, and I dare say you have never thought about it before.

Do you know the story of a certain lady called Penelope, who was the wife of Ulysses, a very celebrated king of whom the world has talked for the last 3000 years—thanks to a poet called Homer, who did him the honor of making him his hero! The husband of Penelope had left her for a long time to go to the wars, and as he did not return, people tried to persuade her to marry again. For peace and quiet's sake, she promised to do so when she should have finished a piece of cloth she was weaving, at which she worked all day long. They thought to get hold of her very soon, but her importunate lovers were disappointed; for the faithful wife, determined to await the return of her husband, unwove every night the portion she had woven during the day; and I leave you to judge what progress the web made in the course of a year!

Now, every part of our bodies is a kind of Penelope's web, with this difference—that here the web unravels at one end as fast as the work progresses at the other. As the little masons put new bricks to the house on one side, the old ones crumble away on another—in this manner the work might go on forever without the house becoming bigger; while, on the other hand, the house is always being rebuilt. People who are fond of building, as some are, would quite enjoy having such a mansion as this on hand!

At your early age, my love, fewer bricks drop out than are added, and this is why you grow from year to year. At your papa's age, just the same number perish and are replaced; and therefore he continues the same size, although in the course of the year he swallows three times his own weight of food. But when I say this, do not suppose it is an offensive remark, or that I think him either too little a man, or too great an eater;

seeing that there are 365 days in the year, and that a quart of water weighs two pounds: I need not say more!

But the next question is, what becomes of all the refuse which this perpetual destruction produces?

What becomes of it? Have you forgotten our steward who looks after everything? He is a more active fellow than I have represented him! To the office of purveyor-general he adds that of universal scavenger. But in the latter department he obtains help. Wherever he passes along, troops of little scavengers press forward, like himself always busy; and while he holds out a new brick to the mason as he hurries by, the little scavenger slips out the old one and conveys it away. The history of these scavengers is a very curious one, and we shall have to speak about it a little further on. They are minute pipes, *i. e. ducts*, spread all over the body, which they envelope as if with fine net work. They all communicate together, and end by emptying the whole of their contents into one large canal, which, in its turn, empties itself into the great stream of the blood. Imagine all the drains of a great town flowing into one large one, which should empty itself into the river on which the town was built, and you will have a fair idea of the whole transaction. What the river would in such a case be to the town, the blood is to the body—the universal scavenger, as I said before. But you will ask further, What does the blood do with all this?—a question which brings us back once more to the liver.

You must have seen, just now, that the pockets of our dear steward would be rapidly overloaded, were he to keep constantly filling them with the old worn-out materials which the builders rejected, unless he had some means of emptying them as he went along. Accordingly, a wise Providence has furnished the body, on all sides, with clusters of small chambers or cells, in which the blood deposits, as he goes by, all the refuse he has picked up, and which makes its exit from the body sometimes in one way, sometimes in another. Now, the cells of the liver are among these refuse-chambers. One may even consider them as some of the most important ones. When the blood has run its course through the lower compartment, I mean the *abdomen*, it collects from all directions and rushes into a large canal called the *portal vein*, which conveys it to the liver. As soon as this canal has entered the liver, it divides and subdivides itself in every direction, like the limbs and branches of a tree diverging from the trunk; and very soon the blood finds itself disseminating through an infinity of small canals or pipes, whose ultimate extremities, a thousand times finer than the finest hairs of your head, communicate with the tiny cells of the liver. There, each of the imperceptible little drops, thus carried into these imperceptibly minute cell-chambers, rids itself—but no one knows how—of a part of the sweepings it has carried along with it. Which done, the little drops thread their way back through other canals as fine as the first, and which go on uniting more and more to each other, like the branches of a tree on their way to the trunk—forming at last one large canal, through which the blood escapes from the liver, once more relieved from its weight of rubbish, and ready to recommence its work.

You are going to ask me, "What is all this to me—this history of the blood and its sweepings? It was the bile you undertook to tell me about, that liquid you spoke of as so necessary for the transformation of the food: we were to get out of the intestinal tubes by the help of the bile, you promised me."

Well, my little impatient minx, it is the history of the bile that I have been relating to you, and what is most remarkable about it is this. You have perhaps heard of those wholesale ragpickers, who make large fortunes by collecting out of the mud and dirt of the streets, the many valuable things which have been dropped there? Well, the liver is the master-ragpicker of the body. He fabricates, out of the refuse of the blood, that bile which is so valuable in the economy of the human frame. This bile is neither more nor less than the deposit left by the little drops of blood in the innumerable minute liver-cells. See what an ingenious arrangement, and in what a simple way two objects are effected by one operation!

Now you have learnt the genealogy of the bile, and the double office of the liver, which benefits the blood by what it takes from it, benefits the *chyme* by what it gives it, and is an economist at the same time—since it only gives back what it has received. This was what I particularly wished to explain to you: the rest you will easily learn.

The bile does not make a long stay in the little cells, it also escapes, by canals similar to those which carry off the blood, after its purification; and which in a similar way unite by degrees together, until at length they terminate in a single canal, communicating with a little bag placed close against the liver, where the bile accumulates between the periods of digestion—so forming a stock on hand, ready to pour at once into the *duodenum* when the latter calls for its assistance. The next time the cook cleans out a fowl, ask her to show you the little greenish bladder which she calls the gall and which she takes such care not to burst, because it contains a bitter liquid which, if spilt upon it, would quite ruin the flavor of the fowl. Such, precisely, is the bag which holds the bile. Moreover, it is close by the liver of the fowl that you will find it placed: and you can convince yourself in a moment by it, that the little provision I tell you of is always stored away therein.

We have also within us a multitude of minute electric telegraphs, which transmit intelligence of all that occurs from one part of the body to another, in a more wonderful manner even than the telegraphs of man's making; later we shall see how they work. By their means the little bag by the liver is made aware in the twinkling of an eye of the entrance of the *chyme* into the *duodenum*, and forthwith the bile returns for some distance by the canal which brought it, and then branches off into a larger one which opens into the *duodenum.*

The liver, on getting this intelligence, sets to work more diligently than ever, and the bile flows in streams into the *duodenum*, where it mixes as it arrives with the current which comes from the *pancreas.* Thus combined, the two liquids flow over the *chyme*, which they saturate on all sides; and here, as I have said, the work of the intestinal canal ends. What is serviceable for the blood is separated from the useless refuse, and nothing remains but to get it out of the intestines. It is true that in their character of tubes these are closed on all sides. But do not trouble yourself: a means of escape is prepared.

Before we part, however, I must apologize for something. I have not described to you what the bile consists of, or what kind of refuse the blood leaves in the liver; nevertheless, as you take an interest in this much-neglected book of nature, you ought to know these things.

It is, however, very difficult to lead you by the hand through so many wonders, where the secrets of nature are all in operation at once, and to explain each as soon as we meet with it. They combine, and progress together like the waves of the sea, where one breath suffices to agitate the whole mass.

When we have talked about the lungs, we will have another word to say about the liver.

LETTER XII.

THE CHYLE.

To-day we have to begin by making acquaintance with a new term. I would willingly have spared you this, if I could, for the word is neither a pretty, nor a well-chosen one, but we cannot get on without it.

You are aware now that the learned, unknown sponsors, who gave names to the different parts of the body, bestowed the odd-enough one of *chyme* on that pasty substance which passes out of the stomach when the cooking is over. We have said quite enough about it, and you know enough of it I am sure. Well! the people seem to have had quite a fancy for the word *chyme*, for they adopted it again, with only a very slight alteration, when they wanted to specify separately the quintessence of the *chyme* (the useful part that is), which has to unite with the blood, and which we have been speaking of as the *gold* of the aliments—this then they called *chyle*. I give you the name as I received it, but have no responsibility in the matter.

In concluding the last chapter I said we were sure to find there was a plan for extracting the best part of the *chyme*, viz. the *chyle*, from the intestinal canal; and a very simple one it is. A complete regiment of those little scavengers lately described, are drawn up in battle-array along the whole length of the small intestine, but especially round about the *duodenum*. There, a thousand minute pipes pierce in all directions through the coat of the intestine, and suck, like so many constantly open mouths, the drops of *chyle* as fast as they are formed. They are called *chyliferous vessels* or chyle-bearers, just as we might call hot-air stoves *caloriferous* or heat-bearers—from the Latin word *fero*, which means to carry or bear. I mentioned before that there were, within the intestine, certain elastic valves which obstruct the progress of the *chyme*, and oblige it to be constantly stopping. There are in fact so many of these, and the skin which lines the intestinal canal is so folded and plaited, that if it were stretched out at full length on a big table, it would cover at least as large a surface as that other skin, with which you are so well acquainted, which entirely clothes the body outside.

Now, the *chyliferous vessels* we have been speaking of insinuate themselves into all the plaits and folds alluded to, and thus they reach at last the very centre of the *chymous* paste, and not a single drop of *chyle* can escape them. They do their work so well, that the separation is effected long before the paste reaches the large intestine; and when that has forced its way through the door which guards the entrance, and which prevents its ever returning again, the *chyle* is already far off on its mission. It has threaded its way along the little pipes, and, always creeping nearer and nearer, is on the high-road to the heart, where it is anxiously expected.

And what becomes of the rest? There is nothing further to be said about it, but that it shares the fate of everything else which, having answered its purpose in its place, is no longer wanted and must be got rid of. Thus in works where iron-stone smelting is carried on, the refuse that remains after the ore is extracted, though available for road-making or other purposes, is thrown out of the manufactory as a useless incumbrance there.

Our history requires us to follow the fate of that golden aliment the *chyle*, which is now in a condition to support the life of the body, and every drop of which will turn into blood—the blood which beats at our hearts, nourishes our limbs, and sets at work the fibres of our brain.

I ought to tell you first that the *chyle*, when it leaves the intestine, is very like milk. It is a white, rather fatty juice, having the appearance, when you look closely at it, of a kind of *whey*, in which a crowd of globules, or little balls if you prefer it, infinitesimally small, are swimming about. Some people, whose curiosity nothing can check, have put the tips of their tongue to it; so I am able to tell you, if you care for the information, that it has rather a saltish taste.

At this point it is what may be called new-born blood, and to carry on the metaphor, blood whose education has yet to be completed. All the elements of blood are there already, but in confusion and intermingled, so that they cannot yet be recognised. A wonderful fact, and one of which I have no explanation to offer you, because among the many mysteries which are silently going on within us is this, that the education of the new-born blood begins entirely of itself in the vessels which are carrying it along. During their very journey, the confused elements are setting themselves in order and forming into groups. In short the *chyle*, when it comes out of the chyliferous vessels, is already much more like blood than when it entered them, and yet one cannot account for the change. It is changed, however; its whiteness has already assumed a rosy tinge, and if it is exposed to the air it may be seen turning slightly red, as if to give notice to the observer of what it is about to become.

You know that all our scavengers uniting together deposit their sweepings in one large canal, which is called the *thoracic duct.* The *chyle* scavengers arrive there just like the rest, and there our poor friend finds himself confounded for a moment with all the dross of the body, as sometimes happens to men who devote themselves to the public good. But the crisis passes in an instant. A little further off, the *thoracic duct* pours its whole contents together into a large vein situated close to the heart, and the blood has no difficulty in recognising and appropriating what belongs to him.

Here, my dear little scholar, we conclude the first part of our story. To eat is to nourish oneself; that is, to furnish all parts of the body with the substances necessary to them for the proper performance of their functions. The mouth receives these substances in their crude condition, the intestinal canal prepares them for use, and the blood distributes them.

After the history of the *preparation*, comes naturally that of the *distribution.*

The first is called the DIGESTION. It is the history of the *Chyle*, which begins between the thumb and forefinger while as yet invisible, hid in the thousand prisons of our different sorts of food, and ends in the *thoracic duct*, when, disengaged from all previous bonds, purified and refined by the ordeals of its intestinal life, it leaps into the blood, carrying with it a renewal of life and power.

The second history is that of the CIRCULATION. It is the history of the *Blood*, that indefatigable traveler, who is constantly *circulating* or describing a circle (the Latins called it *circulus*) through the body; by which I mean that it is continually retracing its steps, coming out of the heart to return to it, re-entering it only to leave it again, and so on without intermission, until the hour of death.

The history of the *Digestion*, which we have just gone through, goes on quietly from one end to the other without any complication.

That of the *Circulation*, which we are about to begin, is mixed up with another history, from which it cannot be kept separate while the description is going on, although the two histories are in reality quite distinct from each other.

The blood describes two circles, to speak correctly: 1st. A wide one, which extends from the extremities of the body to the heart, and back again from the heart to the extremities. 2d. A more contracted one, which goes from the heart to the lungs, and back from the lungs to the heart. Whilst circulating in the lungs, it encounters the air we breathe; and here takes place, between it and the air, one of the most curious transactions imaginable, without which the blood would not be able to nourish the body even for five minutes. This is called RESPIRATION, or the act of breathing.

Digestion, circulation, respiration, the three histories together form but one—that of NUTRITION, or the act of nourishing; in other words, of supporting life.

This is what I called *eating* at first, that I might not mystify you at the beginning with hard words. But now that we are growing learned ourselves, we must accustom ourselves to the terms in use among learned people, especially when they are not more formidable than those I have just taught you.

Our next subject for consideration, then, will be the circulation; and we will begin with the heart, since that is to the circulation what the stomach is to the digestion—viz., master of the establishment. He is a very important person, this heart, as I hardly need tell you. Even ignorant people speak respectfully of him, and I am sure beforehand that his history will interest you very much.

Do you feel as I do, my dear child? I am quite happy at having brought you thus far on our journey, and at being able to take a rest with you at the gateway of the new country into which we are about to enter, like travelers sitting down upon a boundary frontier. What a distance we have come, since the day when I took you by the hand to conduct you inside this little body, of which you were making use without knowing anything about it! How many things we have learned already, and how many more remain to be learned, of which you have at present no idea! I assure you I should be almost afraid myself of what is before us yet, if I did not rely upon my own strong desire to instruct you, and the tender affection I bear to you. Believe me, the greatest of constraining powers is love; and when I get bewildered in the midst of some difficult explanation which will not come out clearly, I have only to place before me those laughing eyes of yours, where sleeps a soul that must soon awaken to consciousness, in order to make the daylight come into my own!

Must I add, too, that I am not working for you only? We are all placed in this world to help each other, and in striving to bring down light into your intellect, and good sentiments into your heart, I am thinking also of those to whom you, in your turn, may render the same good service hereafter, provided I have the happiness of succeeding now with you. This ought to be so, ought it not? You should resolve to be numbered one day among those who have not lived altogether for themselves, but who have given the world something worth having as they passed through it. To-day's labor will have been well employed if, later on, it turns out that this history of the *chyle* has not been told you in vain!

LETTER XIII.

THE HEART.

There was once upon a time a banker, a millionaire, who could reckon his wealth not by millions only, but by hundreds of millions and more ; who was, in fact, so tremendously rich that he did not know what to do with his money—a difficulty in which nobody had ever been before.

This man took it into his head to build a palace infinitely superior to anything that had hitherto been seen. Marbles, carpets, gildings, silk hangings, pictures, and statues—in fact, the whole mass of common-place luxuries as one sees them even in the grandest royal abodes, fell short of his magnificent pretensions. He was an intelligent man, and thoroughly understood the respect due to his riches ; and the common fate of kings seemed to him far too shabby for the entertainment of his dynasty, which he looked upon as very superior to all the families of crowned heads in the world. In consequence he sent to the four quarters of the globe for the most illustrious professors, the most skilful engineers, the cleverest and most ingenious workmen in every department ; and giving them unlimited permission as to expenditure, ordered them to adorn his palace with all the wonders of science and human industry.

Science, and human industry, and unlimited means—

what will they not accomplish? No wonder that nothing was talked of for a hundred miles around but the magic building—of which, by the way, I do not venture to give you a description, because it would carry me too far away. Let it suffice to say, that never Emperor of China, Caliph of Bagdad, or Great Mogul had such a habitation as our banker, and for a very good reason—he was twenty times as rich as any such gentry as I have named ever were in their lives.

When all was finished one trifling flaw was discovered: the place was not supplied with water. A spring-seeker, who was summoned to the premises, could only discover a small subterranean watercourse, a sort of zigzag pipe, formed by nature, between two beds of clay, in which the rain of the neighborhood collected as in a sort of reservoir. The water was neither very clear nor very plentiful, as you may imagine; and the professor appointed to examine it, having begun by tasting it, made a horrible face, and declared there was no use in proceeding any further; for it had a stagnant flavor which would not be agreeable to my lord.

To the amazement of every body, my lord jumped for joy when he heard this unpleasant news. It was proposed to him to fetch water from a river which flowed a few miles' distance off; but he would hear of nothing of the sort. What he wanted was something new, unexpected, impossible—that was his object throughout. He took a pen and drew up at a sitting the following programme, which caused our poor professors to open their eyes in dismay:—

1st. We will use the water on the premises.

2ndly. It shall flow night day and in all parts of the palace at once.

3rdly. There shall be plenty of it, and it shall be good.

The professors looked at each other for some time without speaking, and the gravest of them, whose fortunes and characters had been long ago established, suggested that they should simply give my lord and his money the slip, and so teach him to make fools of people another time!

But the youngsters, less easily discouraged, cried out against this with one accord. They declared that the honor of science was at stake, and that they ought to return impudence for impudence, by executing to the letter the impertinent programme! At length, after much discussion and many propositions made against all hope, and thrown aside one after the other as impracticable, a sudden inspiration crossed the brain of an engineer who had not yet spoken; and the following is what he proposed:—

What prevented the water from being sweet and fit to drink, was the want of movement and air. What had to be done, therefore, was to erect a pump, but a pump provided with numberless small pipes, extending to the watercourse in all directions, and so arranged that by means of them it should be able to draw up the water from all the corners and windings where it lay stagnating, and then forcing it forward into a pipe terminating in a rose, like that of a watering-pot, whence it should gush out to fall down in fine rain, into a reservoir in the open air. From thence another action of the pump was to bring it back well aerated, to send it once more into a large pipe with numerous lesser ramifications, which should convey it into every corner of the palace.

Up to this point all seemed practicable, but the hardest part had not yet come. The great difficulty was how to supply this enormous consumption with so slender a runnel of water as the one at their disposal. But our engineer had provided for this by a stroke of genius.

Under each of the taps (always kept open), which were dispersed all over the palace, he would place a small cistern, from the bottom of which should go a pipe communicating with the body of the force-pump which drew up the water from the original watercourse. By which means the water which ran from the taps would be taken up again and go back to feed the reservoir in the open air ; whence it would again return to supply the taps ; and so on and on, the same water continually keeping the game alive, as people call it. Have you not sometimes seen at a circus or theatre a large army represented by a hundred supernumeraries, who file in close columns before the audience, going out at one side of the stage and coming in at the other, following close at each other's heels indefinitely ? By a similar artifice the engineer would change his meagre little runnel into an inexhaustible fountain. The water drawn up from the watercourse by each stroke of the pump would fully compensate for what was used in its passage through the palace by the inhabitants. Lastly, as it might sometimes happen that the said inhabitants washed their hands under the taps, the water on its return to the cisterns, was to pass through a series of small filters, in order to cleanse it from any impurity it might have contracted by the way. Always flowing, always limpid, it would soon lose every trace of its original source, and might defy comparison with the water of any river in the world !

A unanimous buzz of congratulations welcomed this plan, at once so simple and so bold, and our professors thought their troubles were over, but they were not at the end of their difficulties yet. When it came to the actual erection of the machine, (naturally a most complicated one, as it had to set a-going a quintuple system of pipes—pipes from the water-course to the pump, pipes from the pump to the reservoir, pipes from the reservoir to the pump, from the pump to the taps, and from the taps to the pump again,)—our banker, who had got amused and excited as they went on, conducted them to a small dark closet, only a few square feet in size, concealed in a corner of the large apartments, and informed them with a laugh that he had no other place to offer them. Besides which, he made them understand that on account of its situation, there could be no question of furnaces or boilers being set up there (he detested equally coal-smoke, fires, and explosions)—nor of workmen employed about the machine (it would not be decent to have them going up and down the front staircase)—nor above all, of the frightful brake-wheels always screeching and grinding, the unwieldy pistons rising and falling with a noise sufficient to give one the headache. He himself slept near the little dark closet, and the slightest noise was fatal to his repose. Having explained all this, the rich man curtly made his bow and retired.

For once our professors owned themselves beaten. They had come forward quite proud of their invention, and now they were received, not with ecstasies of delight, but with fresh demands, more ridiculous even than the first. They were decidedly being mystified, and were preparing in consequence to pack up and begone, furious, and swearing by all their gods that they would never again expose science to see itself disgraced by a purse-proud vulgarian's scorn; when, lo! happily, a good fairy, the special friend of learned men, came passing by that way. She raised her enchanted wand with the tip of her finger, and all at once a little girl dressed in rags appeared in the midst of our astonished professors. Without giving them time to recover themselves, the child put her hand into the little patched waist of her dress, and drew forth a rounded object, about the size of her closed fist from which hung a quantity of tubes spreading in all directions.

"See!" cried she; "here is the machine your banker demands of you."

Picture to yourself a small closed bag, narrowing to a point at the end, and separated within into two very distinct compartments by a fleshy partition which went across the inside from the top to the bottom. Such was the object held up by the little girl. From each of these compartments issued a thick tube, ramifying into endless smaller ones; and they were moreover each surmounted by a sort of pouch, into which ran another tube, of the same description as the first. Each of these four portions (the two compartments and their pouches) was in constant but independent motion, distending and contracting alternately; and by carefully examining the noiseless play of this singular machine, (the walls of which were, by the magic power of the fairy, rendered transparent to the bystanders,) the learned assembly were very soon enabled to convince themselves, that it fulfilled all the monstrous conditions exacted of them by the fantastic millionaire.

All was in movement together, I told you; but let us begin at one end. The right-hand compartment and its pouch represented the first pump; the pump employed to draw, by the same stroke, the water from the stagnant channel, and that from the taps. It was perfectly easy to distinguish the two systems of pipes, and how they united together at the small pouch on their arrival. When this was distended, a vacuum was created inside, which was instantly filled by the liquid from the tube which ran into it, (do not ask me why or how; I will explain that presently). When it contracted again, the liquid which had just entered was not able to get back, being prevented from so doing by a very ingenious and simple contrivance, which requires a brief explanation.

Take off the lock from your chamber-door, which opens inside; then, standing outside, push against it with your shoulder, and you will get in without any difficulty. But when you are in, try to push the door open again with your shoulder in order to get outside into the passage, and you will find that you will not be able to pass through, and this simply because it does not open on that side.

Which was exactly what happened to the liquid in the pouch!

The door between the tube and the pouch only opened inwardly, and the liquid finding itself pressed on all sides in proportion as the pouch contracted more and more, and unable to return, was obliged at last to make its way through another similar door which led to the large compartment below. Here the same game recommenced. The compartment which had distended itself to receive it, contracted in its turn, and the liquid finding the road again barred behind it, had no choice but to force its way through the tube which led to the air-reservoir.

Here commenced the work of the second pump,—the pump of the left compartment. The little pouch, when distended, was filled by the liquid from the reservoir, and then forced it forward into the large compartment below, always by means of the same process. This compartment again drove it, by a powerful contraction, into the large conducting tube charged with the office of its general distribution throughout the body. At the end of all which, it returned once more into the right-hand pump as before, to pursue the same course again, &c., &c.

Thus, as you see, the whole mechanism turned upon two little points of detail, of the simplest description possible; namely, first, on the entrance-doors only opening on one side; and secondly, on the elastic covers of the pouches and compartments distending and contracting spontaneously. It was the prettiest thing in the world to see this unpretending-looking little bag working thus, quite naturally, without a suspicion that it was solving a problem which so many men, proud of their science, had given up as hopeless. Certainly here was a machine which made no noise! Once installed in its dark closet, it would have been necessary to place your hand upon it to find out that it moved at all. My lord could certainly sleep beside it without disturbance.

"How much do you want for it?" said they to the poor little beggar girl. "Name your price; have no fear; we will pay you anything you wish."

"I cannot give it to you," replied the child; "I need it too much myself: IT IS MY HEART. Now that you have seen it, make another like it, if you can." And she disappeared.

It is said that the engineer, who longed to see his idea carried out, tried hard to construct a similar machine with gutta-percha and iron wires, and to set it in motion by electricity. But history does not tell us that he succeeded, and we have yet to ask ourselves whether the richest man in the world, aided by the wisest men in the world, could ever provide himself with a miracle of wonder, such as the ragged child had received as a free gift from the hands of a gracious Creator.

LETTER XIV.

THE ARTERIES.

If you have thorougly understood the story I last told you, my child, it will have revealed to you the whole mystery of the *circulation of the blood*, and you are at the present moment wiser than all the learned men of antiquity and the middle ages, for they had none of them the faintest surmise of the truth.

It may, perhaps, seem odd to you that men should have existed for upwards of five thousand years without making inquiry into a matter which so closely concerned them, and which was so easy to find out. Is it not almost incredible that so many hearts should have beaten for so long a period without any of their owners having felt a wish to know exactly *why?* Yet so it is. The action of the heart and the flow of the blood have not been understood for much more than two hundred years, and the man whose name is attached to this great discovery richly deserves that we should say a few words about him.

He was called Harvey. He was an Englishman; physician to King Charles I., who was beheaded in 1648; and when he first ventured publicly to teach that the blood was constantly circulating from one end of the human body to the other, perpetually returning and retracing its steps, a great scandal was created in the world. He was called a fool,—an impertinent innovator,—a madman. His words shattered old doctrines, and he only received for his reward all the petty annoyances which men are apt to lavish so freely upon any one who tells them something new; because—do you see?—it is so disagreeable to be disturbed in one's habits and preconceived ideas.

Harvey is not the only one in the history of mankind who has committed the sin of being right in defiance of the opinions of his age. It is true posterity takes account afterwards of the labors of genius, and inscribes a fresh name upon her list. But one must pay for this glory in one's lifetime. One cannot have everything at once.

This is an old story, my child, but always new nevertheless; and for my own part it is, I own, one of my pleasures to amuse myself by reflecting how much cause for laughter three-fourths of the great men of the present day are providing for the little girls who shall be alive two centuries hence. Time is a great avenger, and puts many things and men in their proper places.

Let us pause here a moment while we are speaking of Harvey. I should be curious to know what any one of the courtiers of Charles I., bedecked in feathers, ribbons and laces, would have said to the valet who would have placed the excellent Harvey, with his insane invention, above his most gracious majesty, the lord and king of all Great Britain! And yet what is his most gracious majesty to you to-day? What do you owe to him? in what does he interest you? While you can never hear the name of Harvey pronounced without remembering that you are under many obligations to him! A thousand years hence, when society shall have made the great progress which may reasonably be expected, the name of Harvey will be familiar to every one who owns a heart, while that of Charles I. will be only a vanished shadow; a souvenir lost in the maze of history.

Our debt of remembrance paid, let us return to the heart—the little closed bag which labors so prettily. We must now inquire the real names of whatever has figured in our story.

The two great compartments are called *ventricles*, the two small pouches *auricles*, and they are also distinguished as being on the right or left side;—*right ventricle, left ventricle, right auricle, left auricle.*

The inner doors on which depends all the action of the machine, are called *valvelets.* By-and-bye, when the pump and the steam-engine are explained to you, you will meet again with these treacherous doors, which never allow what has once entered to go back again; but then we shall call them *valves.*

The air-reservoir, I need scarcely tell you, is the *lung*, to which the blood goes to put itself in contact with the air.

The subterranean watercourse, of which I hope we have talked long enough, is *the small intestine*, in which the *chyle* collects; and the tubes which run into it are, of course, the *chyliferous vessels*, the only channels by which anything reaches the heart which has not previously gone out from it.

The tubes of distribution, which run out from the machine in all directions, are called with us *arteries;* the return tubes, which bring back the water to the machine, are called *veins.*

Finally, we have not exactly the *filters* employed to clear the water from the impurities contracted as it goes along, for no such thing exists in us. There are in our case the refuse-chambers of which I have already spoken, in connexion with the liver, where the blood disembar rasses itself of any useless materials, and from which it comes out with clean pockets, so to speak, reverting to the comparison of which we have already availed ourselves.

As you see, then, everything comes round again ; and the bright idea which our professors hit upon in order to satisfy the caprice of the banker is exactly carried out in your own body, only a thousand times more perfectly than could have been done by them all, even with all their science added to all his money.

I mentioned that the shrewdest of the party boasted about making an artificial heart. But, let me tell you, there is one thing I would have defied him to imitate, by any expedient he could devise, and that is the inimitable construction of the *arteries* and *veins*, and the incomprehensible delicacy of their innumerable ramifications.

Let us talk a little about these marvellous tubes, and begin with the arteries, which have the most important part to play.

Did you ever see a doctor try the pulse of his patient? Take hold of your own wrist and search a little above the thumb. You will soon find the place and feel something beating against your finger. There is an artery which passes there, and the little beating you feel is the rebound of the pulsations of your heart. Every time that the left *ventricle*, by contracting itself, chases the blood into the arteries, these, of which the tissue is very elastic, become distended all at once, and then contract again, repeating the process whenever a fresh gust of blood arrives, so that their movement is exactly regulated by the movement of the heart. It is true the two movements are in a contrary direction ; that is to say, the artery becomes distended, while the heart contracts, and contracts when the heart enlarges itself; but that makes no difference to the doctor. What he wants to know is, with what force and rapidity the heart of the patient beats, and I will explain why. It is an interesting point in the history of circulation.

When you were very little—very little indeed, my dear child—your heart beat from 130 to 140 times in a minute. Afterwards the beats sank to 100 per minute; then to fewer still. At present I cannot tell you the precise number: perhaps, about ninety. When you are a grown-up young lady, it will beat about eighty times in the minute; when you are a mother, about seventy-three times; when a grandmother (if such a blessing be granted you), only from fifty to sixty times, perhaps even fewer. People tell of an old man of eighty-four whose heart beat only twenty-nine times in the sixty seconds.

Observe that in all my calculations I have taken special care to prefix the word *about* to the numbers mentioned. And this because, in point of fact, the heart is a capricious creature, which has no exact rules to go by. It changes its pace on every occasion—fear, joy, every emotion which agitates the soul, quickens or retards its movements; and derangements of health may be detected by its pulsations, which are infinitely varied in character. In fever, for instance, which is nothing but a race of the blood at full speed, the hearts of grown-up people beat as quickly as those of little children; sometimes, indeed, more quickly still. In certain maladies it goes with great sudden leaps, like a galloping horse; in others it trots in little jerks; while in some cases it moves slowly and wearily, and its throbs are so weak that one can scarcely feel them.

These pulsations, then, afford important revelations to the doctor. The heart is for him a gossiping confidant, who lets out the secrets of illnesses, however closely they may fancy themselves hidden in the remote depths of the body. When the doctor lays his finger on the patient's pulse, it is precisely the same thing to him as if he had laid it on his heart, only with this difference, that the one is much less difficult to do, and much sooner done than the other.

The artery of the wrist is in fact a small heart, not only because it follows all the movements of the large one, but because it carries forward the work which the other begins, and assists also in propelling the blood to the furthest extremities of the limbs, driving it on in its turn at each of its own contractions. Imagine a fire-engine, whose pipes should take up and drive forwards along their whole length the water which is thrown upon the fire, and you will have some idea of the marvellous machine which is at work in our behalf within us. Nor are you to suppose that the wrist-artery is a specially privileged one, because it has been chosen to hold intercourse with physicians. All the others are equally serviceable; and if they cannot all be used for "feeling the pulse," it is because they are generally more deeply buried in the flesh, where it is not easy to reach them.

Observe your mother when she is packing a trunk, and you will see that whatever she is most afraid may be spoiled, she is most careful to put in the middle, so that it may be least exposed to accidents. And this is what a kind Providence has done with the arteries, which have the utmost cause to dread accidents; whilst the veins, which are much better able to bear rough usage, are allowed to wander about freely just under the skin. But when the bones happen to take up a great deal of room, and come near the skin themselves, as is the case in the wrist, the artery is forced, whether he likes it or not, to venture to the surface, and then we are able to put our fingers upon him.

And there are others in the same sort of situation; the artery of the foot for instance. But only just think how far from agreeable it would be to have to take off your shoe and present your foot to the doctor!

The artery which passes to the temple, just by the ear, is another affair. That would answer the purpose very well in fact, and I even advise you to make use of it when you want to feel your own pulse. It is more easily found than the other even, and its pulsations are still more easily perceptible. Nevertheless, when all is said and done, it is better for the doctor to take his patient by the hand than by the head. Merely as a matter of good manners.

I will now make you acquainted with the principal arteries, and the manner in which they distribute the blood through the body.

The whole of the blood driven out by the left *ventricle* at each of its contractions, passes into one large canal called the *aorta*. The *aorta* as it goes away at first ascends; then bends back in a curve; and from this curve, which is called the *arch of the aorta* (from its shape) diverge right and left, certain branch-pipes which carry the blood into the two arms and on each side of the head; and which are, in fact, the beginning, or upper end, of those whose pulsations we feel with our fingers in the two wrists and at the temples.

The supply to the upper part of the body being secured, the *aorta* begins to descend. But now imagine of what importance it must be, that this head-artery—the foster-father of the whole body—should be sheltered from every accident. The *aorta* once divided, death is inevitable; you might as well have your head cut off at once; and thus it has been fixed in the best—that is to say, the safest—place. Of course you know what is meant by the *backbone* or *spine*, called also the *vertebral column*, in consequence of its being made like a sort of column composed of a series of small bones fastened together, which are named *vertebræ*. Touch it and feel how solid it is, and how few dangers there can be for anything placed behind it. Well, that is the rampart which has been given to the *Aorta*. As this descends, it slips behind the heart and takes up its place in front of the *vertebral column* which it follows all the way down the back, just to the top of the loins. There it is, so to speak, almost unassailable; in fact hardly any cases are known of the *Aorta* being wounded; to get at it, it would be necessary to bestow one of those blows which used to be given in the time of the Crusades, which cut the body in two. There was an end of the *Aorta*, as of every thing else then; it was unfortunately not worth talking about any longer!

The next time you see a fish on the table, ask to be shown the large central bone. It is the fish's *vertebral column*, and it will give you an idea of your own, for it is constructed on the same plan. You will perceive a blackish thread running all along it—that is *the aorta.*

As it descends, the *aorta* sends off on its passage a great number of arteries which carry the blood into all parts of the body. Arrived at the loins it forms a fork; dividing into two great branches, which continue their descent, one on each side the body, down to the very extremities of the two feet.

As you perceive, dear child, this is not very difficult to remember. A large fork, whose two points are at the tips of the feet, the handle of which curves at the top like the crook of a crozier; from this curve come four branches, which pass into the two arms and to the two sides of the head—and this is the whole story. But of course, it would be another affair were I to enter into the detail of all the ramifications. Here it is that all engineers, past, present, and future, are baffled, defeated and outdone! Choose any place you please upon your body, and run the finest needle you can find into it what will issue from the puncture?

"Thanks for the proposal," you say; "I have no occasion to try the experiment, to discover that blood will come out."

You say that very readily, young lady; but have you ever asked yourself, what is implied by your being so sure before hand that you can bring blood from any part of your body if you choose to prick it, though never so slightly? It implies that there is not on your whole frame a spot the size of a needle's point, which has not its own little canal filled with blood; for if there were such a one, there at any rate the needle would pass in without tearing the canal, and causing the blood to flow out. And now count the number of places from the top to the bottom of your dear little self, on which one could put the point of a needle, and even when you have counted them all, do not fancy you have arrived at the number of the tiny tubes of blood. Compared to these, your needle is a coarse stake, and tears not one but a thousand of these little tubes in its passage.

That seems to you rather a strong expression, does it not? But let me make good my boldness. A needle's point is very fine, I admit; but a person who could not see it without spectacles must have very poor sight. Whereas the last subdivisions of the blood-tubes are so attenuated, that the best eyes in the world, your own included, cannot distinguish them. You are astonished at this, and yet it is nothing compared to what follows.

No doubt you have heard of the microscope,—that wonderful instrument by which you may see objects a thousand, a hundred thousand, a million times, if necessary, larger than they really are. With the microscope, therefore, as a matter of course, we can see a good many of those tiny canals which elude our unaided sight. But, alas! we discover at the same time that these are by no means the last subdivisions. The canals invisible to our naked eyes subdivide themselves again into others, and these into others again, and so it goes on, till at last—the man at the microscope can see no more, but the subdivisions still continue.

You were ready to exclaim, at my talking of thousands of canals being torn by a needle in passing through; but had I even said millions, it may be doubted whether I should have spoken the whole truth.

Besides, when you consider the office of the blood, you can easily understand that if there were a single atom of the body left unvisited by him, that atom could never be nourished. Do I say nourished? I have made here a supposition altogether inadmissible; it could have no existence at all, since it is the blood only which produces it.

These imperceptible canals of blood have been called *capillaries*, from the Latin word, *capillus*, which means a hair; because the old learned men, who had no suspicion of the wonders hereafter to be revealed by the microscope, could think of no better way of expressing their delicacy, than by comparing them to hairs. Very likely they thought even this a great compliment, but your delicate fair hairs, fine as they are, are absolute cables—and coarse cables too, believe me, compared to the *ca-*

pillary vessels which extend to every portion of your body.

Observe further, that each of these arterial *capillaries* is necessarily composed (being the continuation of the large ones) of three coats enclosed one within the other, which can be perfectly distinguished in arteries of a tolerable size; add to this that within these coats there is blood, and in the blood some thirty substances we know of, not to speak of those we do not know; and then you will begin to form some notion of the marvels collected together in each poor little morsel of your body, however minute a one you may picture to yourself.

LETTER XV.

THE NOURISHMENT OF THE ORGANS.

When I said formerly that our dear and wonderful steward the blood, was everywhere at once, you little suspected the prodigies involved in that *everywhere.* But you will have a glimpse of them now, when I tell you it is at the extremities of the *capillary arteries* that he carries on his distribution of goods, and accomplishes a mysterious act of nutrition; a wonder much greater even than that of which we have just spoken. Here, indeed, the question is no longer mechanical divisions, whose delicacy, surprising as it may be, is yet within our powers of comprehension. What is more surprising still, what moreover we cannot comprehend at all, is the delicate sensitiveness of tact—I would almost say of instinct—with which each one of the million millions of tiny atoms of which our body is composed, draws out of the blood—the common food of all—exactly that aliment which is necessary to it, leaving the rest to his neighbor, and this without ever making a mistake.

You have never thought about this; for children go on living at their ease, as if it was the simplest thing in the world to do; never suspecting even that their life is a continued miracle, and never, of course, therefore, feeling bound to be grateful to the Author of that miracle. And alas! how many hundreds of people live and die children in that respect.

But what would happen, I should like to know, if the eye took to seizing upon the food of the nail, if the hairs stopped on the way what was intended for the muscles, if the tongue absorbed what ought to go to the teeth, and the teeth what ought to go to the tongue? Yet what prevents their doing so? Can you tell me? They all drink alike out of the same cup. The same blood goes to furnish them all. The substances that it brings to the eye are the same as those which it brings to the nail; and nevertheless the eye takes from it that which makes an eye, and the nail that which makes a nail.

How is this done, do you think? that is the question.

When the doctors reply to this, that each organ has its peculiar sensibility, which makes it recognize and imbibe from the blood one particular substance and no other, they are strangely mistaken if they flatter themselves that they have really answered anything. They have done nothing but reproduce the question in other words, for it is precisely that sensibility which requires explanation, and to tell us that it exists, does not explain much, you must own. If you were to ask why you had got a headache, and some one were to reply that it was because your head ached, you would not be much the wiser I fancy.

Each of our organs, then, may be considered as a distinct being, having its separate life, and its particular likings. These organs behave towards the blood like men who recognize some friend in a crowd, and proceed to seize him by the arm; and when I told you just now that they never made a mistake, I spoke of their regular course of action in ordinary circumstances. Like men, they also make mistakes sometimes, in certain cases; and take one substance for another, or do not recognize the one they are in need of; an unanswerable proof that at other times they exercise a sort of discernment, and do not act by a sort of fatality, as one might be tempted to believe. Look at the bones, for instance. They are composed of *gelatine* (which cooks serve up under the name of meat-jelly, but which would be more properly called bone-jelly), and of phosphate of lime, a kind of stone of which we have spoken before, if I remember rightly, and from which they get all their solidity. Originally, the substance of the bone is entirely gelatinous, and the phosphate of lime deposits itself therein by degrees, as time goes on, and always in greater abundance as we advance in age.

Properly the bones borrow only gelatine and phosphate of lime from the blood. But when they come to be broken, their texture or *tissue* inflames in the fractured place; and then it changes its tastes, if I may so express myself; and, lo and behold, extracts from the blood that which forms certain little fleshy shoots, which unite together from the two sides of the fracture, and so mend the broken bone. Here is one exception to the rule.

Again, in certain diseases, the bones suddenly quarrel with the phosphate of lime; they will not hear of it any longer, they will not accept a fresh supply; and as the old wears out by degrees, by reason of the continual destruction of which I spoke the other day, the bones become more and more enfeebled, and soon can no longer support the body. A second exception this.

Finally, when old age comes on, the bones end by being so much encumbered with phosphate of lime, that they have no room to admit the fresh supply which keeps coming to them in the blood. What becomes of it then? It goes to seek its fortune elsewhere; and there are charitable souls, who forgetting their instinctive antipathies, consent to give it hospitality, though much to the prejudice of the poor old man himself, who is no longer served so well as formerly, by the incautious servants who have allowed themselves to be thus fatally beguiled ; but no one consults *him*. It is the arteries especially, and sometimes the muscles, which take this great liberty, and it is not unusual among old people to meet with these fairly *ossified*—that is to say, changed into bone, thanks to the phosphate of lime with which they have consented to burden themselves. This is a third exception, and I will spare you any others.

What may we infer from all this, my dear child? Well, two things. First, that we know nothing at all about the whole affair ; a fact which at once places us on a footing with the most learned philosophers in the world. Secondly, that our body is a perpetual miracle ; a miracle which eats and drinks and walks, and which we must not look down upon for so doing : for God dwells therein. I should have to come back to this at every turn, if I wanted to fathom everything I have to tell you about. Each tip of hair which you grow, is an incomprehensible prodigy which would puzzle us for ever, if we did not call to our aid those eternal laws which have made us what we are, and to which it is very just our spirits should submit, since we could not exist for one second were they to cease from making themselves obeyed in our bodies.

Reflect on this, my dear little pupil. Young as you may be, you can already understand from it, that there is above you something which demands your respect. The good God, to whom your mother makes you pray every night, on your knees, with folded hands, is not so far off as you might perhaps suppose. He is not a being of the fancy, secluded in the depths of that unknown space which men call Heaven, in order to give it a name. If His all-powerful hand reaches thus into the innermost recesses of your body, His voice speaks also in your heart, and to what it says you must listen.

LETTER XVI.

THE ORGANS.

Contrary to my custom, my dear child, I made use, in the last chapter, of a new word, without giving an explanation of it.

I spoke to you of *our organs*, and we have not yet ascertained what an *organ* is.

You probably knew what I meant, because it is a word which is used in conversation and pretty well understood by everybody. But I am bent upon giving you a more exact idea of it, for the trouble will be well bestowed. If I did not do this at once it was because there is a good deal to tell about, and that would have carried me too far away from my subject.

Organ, comes from the Greek word *organon*, and means *instrument*. It was used particularly to signify instruments of music, so much so that our word "organ" comes from it. Our bodily organs then, are *instruments*, or *tools* if you like it better, which have been given to us, wherewith to perform all the acts of life; and as there is not one part of the body which is not of use to us for some purpose or other, our body is, in point of fact, from head to foot a compound of *organs*. Thus the hand is the tool which we make use of to lay hold of anything—so an *organ;* the eye is the instrument of sight—so an *organ;* the heart is the machine which causes the blood to circulate—so an organ; the liver fabricates the bile—it is an organ therefore; the bones are the framework which support the weight of the body—so organs; the muscles are the power which sets the bones in movement—organs also, therefore; the skin is the armor which protects them—so an organ: in fact everything within us is an organ. If there was any corner of our body which was not an organ, it would be useless to us, and we should not, therefore, have received it, because God makes nothing without a use.

Here lies the secret of that great miracle which is called life. I do not know whether you will be able to understand me thoroughly, but open your ears, as if some one was going to explain addition to you; this is not more difficult.

Life is in reality the total of an addition sum. Each one of our organs is a distinct being which has its particular nature and special office; its separate life consequently; and our individual life is the sum total of all these lesser lives, independent one of the other, but which nevertheless blend together by a mysterious combination, into one common life, which is everywhere and nowhere at the same time. It follows from this, that the more organs a being has, the greater is the sum total; the more, consequently, is life developed in him. Remember this when we begin to study life in the lower animals. In proportion as you find the number of *organs* diminish, you will find life diminishing in power, until we arrive at beings who have, as it were, only one organ apparent, and whose life is so insignificant, that we have some difficulty in giving an account of it, and are saying the utmost that can be said in calling it life at all.

But this comparison of life to the total of an addition sum, is too dry; and, although it has its appropriate side, yet it might give you a false idea of life; which is what always happens when one tries to solve inscrutable questions and hidden mysteries by a matter-of-fact illustration.

Let us try for something more to the purpose.

I told you that the Greek word *organon* was applied especially to instruments of music. Well, let us consider our organs as so many musical instruments. You have, probably, sometimes been at a concert. Each of the instruments in the orchestra performs its own part, does it not? The little flute pipes through all its holes; the double-bass pours thunder from its chords: the violin sighs with his; the cymbals clash; the Chinese bells dance to their own tinkling; all go at it in their own fashion, each independently of the other. And yet, when the orchestra is in good tune together, and well played, you hear but one sound; and to you the result of all these various noises, each of which would have no meaning alone, is music composed by some great artist whom you do not see. It is no longer a flute, a double-bass, or a violin which you hear; it is a symphony of Beethoven's, an oratorio of Haydn's, or Mozart's overture to *Don Juan*.

Life is just like this. All the instruments are playing together, and there is but one music; music written by God.

But wait! when I say *life is just like this*, let us come to an understanding. Life is *some*thing like it, that is all, for as to telling you what life is, I shall not attempt it. I know nothing about it, do you see, though that is a painful confession to have to make to a pupil; but in this case it does not distress me, and you are welcome to hunt the world through for a master, who in this matter does know anything. I could make a hundred other comparisons, but they would all fail in some point or other. Shall I tell you where this one fails? In an orchestra there is always a musician by the side of the instrument. Now with us we see the instrument well enough, but we cannot see the musician.

You are inclined to ask me, perhaps, why I am wasting so much paper to-day in talking to you about organs, instead of going on tranquilly with our little history of the circulation. But I told you just now that the secret of life lies in the organs, and before entering upon the history of life, I ought to have begun with them. It is there all the books begin which treat of the subject we are studying together, and if you had one in your hands at this moment, it would teach you that all creatures whatsoever are divided into those which have organs and those which have none—that is, into *organic* and *inorganic* beings* (*in* stands here for *not*, as *in*complete means not complete).

This is, in fact, the starting point for the study of nature, and there are many other things besides which I ought to have told you before I began. But we went straight ahead, without looking at what we were leaving behind, satisfied with turning aside from time to time to pay our debts.

And while I am making my confession, I ought to tell you all. You would probably only have listened to me with half an ear, if I had begun at the beginning. There is a proverb which says—"The appetite comes with eating." I do not advise you to follow this proverb too closely at dinner, for it might mislead you sadly. But it is always true when applied to learning; it is what one knows already that gives one a taste for learning more. If I have been making you bite at the organs to-day, which is rather a tough morsel, it was because I fancied that your appetite had begun to come. Was I wrong?

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* A lump of iron is the same throughout. Each of its parts has the same properties and the same uses. It has no organs, it is an *inorganic* being. A rose tree has flowers, which are differently made from its leaves, and serve a different use: a root which sucks up the precious food of the earth; a bark which is of a different nature from the wood, and serves a different purpose. It has organs; it is an *organic being*: all animals and vegetables are *organic beings*.

Let us now return to the blood which nourishes the organs.

LETTER XVII.

ARTERIAL AND VENOUS BLOOD.

It is at the extremity of the capillary arteries, as we have said, that the incomprehensible prodigy of the nourishment of our organs is accomplished. This done, the next thing is for the blood to return to its starting-point; and here recommence those infinitesimally minute wonders of which we have already spoken. Close upon the capillary *arteries* follow the capillary *veins*, equally fine and imperceptible as the others. These take possession of the blood everywhere at once, without allowing it a moment's respite, and it is thenceforth on its road of return, travelling back again to the heart.

Where do the veins begin? where do the arteries end? No one can say precisely, since the last ramifications of each elude the eye of man, however much it may be aided by the admirable instruments which his genius has invented. Nevertheless, although no one has ever ascertained the fact by sight, there is one thing I can tell you—namely, that our minute veins are a continuation of our minute arteries, and that it is the same canal which as it lengthens out turns from an artery into a vein, without any interruption; the substances destined for the nourishment of the organs passing through its walls, as moisture passes through our skin when we perspire.

But if nobody has seen this, say you, how can they know it for a fact?

Let me explain. In man, and in the animals which come nearest to man in structure, it has never been seen; but it has been seen elsewhere. This requires a little explanation, and you will not regret my giving it hereafter. It has its interest, I assure you.

When you put your hand on your throat, how does it feel to you? *Warm*, does it not? And when you take hold of a kitten or a bird, how do they feel? *warm* in the same way. Now, then, can you tell me whence comes this warmth? But to save time I will answer the question myself. It comes from their and your *blood*, which is itself warm, and we shall soon see why. You have no idea of all the curious facts wrapt up in that little phrase, "You are warm-blooded;" your blood is warm. But it has not got warm of itself; bear that well in mind.

Now if you touch a frog, a lizard, or a fish, how do they feel to you? Cold, of course, you answer. But I ask why? A question you will answer in the same way as the other. Because their blood is cold, they are "cold-blooded."

Precisely; and while you are about it you may add that, if their blood be cold, it is because it has not been warmed as yours is. Do not be impatient, we shall make all this clear at the proper time and place.

Now in the cold-blooded animals, such as serpents, frogs, tortoises, lizards, fishes, and others, the blood circulates as it does in us, and what is more, it does so, thanks to a machinery very similar to our own. But, as you may imagine, a machine which produces warmth must be constructed in a more perfect manner than a machine which produces no warmth; and to speak truth, without flattering you, there is a little difference between you and a frog, and it seems natural enough that the body of a frog should be more clumsy in structure than yours.

It is the old story of the poor man being not so well lodged as the rich; but putting aside rich and poor, who are all human beings alike, let us take one of those lovely dolls who walk, and move their arms and head, and say papa! and mamma! and compare it with a cheap bazaar doll which you can get for a penny. Both are made, in the main, in one way. Each has two arms, two legs, a mouth, a nose, eyes, &c.; but what a difference in the details of the two! and what infinitely more pains have been bestowed on one than on the other!

Well, cold-blooded animals are, so to speak, *penny doll* animals, by comparison with ourselves. Like us they have arteries and veins, but there is not near so much workmanship in them; and that marvellous delicacy of the capillary extremities, which in man and in the warm-blooded animals drives the close observer to despair, does not exist to trouble us in these others. It is true that with the naked eye we are still unable to see everything, even in them; but with the help of the microscope the whole is laid open to us—the extremities of the arteries and the extremities of the veins; and it was here that what I was telling you of, just now, was observed and discovered,—namely, that the end of the artery changes into a vein, without any interruption in the tube. It was these very observations upon fishes and frogs, which eventually gained the day in favor of Harvey's ideas on the circulation of the blood, at which the learned men of his own age had laughed so much. He was dead by that time it is true, as has happened but too often in such cases, but do not let us pity him too much! He who has had the rare good-fortune to lay hold of a new truth, and launch it into the world, is suf ficiently recompensed in advance. If he also craves after the flattering voice of man's approbation, and the toylike pleasure of personal triumph, he is after all but a child, unworthy of the great part God has given him the privilege of playing.

A child, did I say? Then how rude you must have thought me, dear child! And as a punishment, you are perhaps going to remind me that I have once more fallen into my old bad habit of wandering away from my subject. Never mind, I am going to return to it at once.

How can one distinguish—you will ask me—an artery from a vein, so as to be able to determine which is a vein and which an artery?

In many ways, I reply. First of all, an artery, as I told you lately, is composed of three coats, of which the principal, *i.e.* the inner one, is tough and elastic, whereby the artery is enabled to force the blood forward in its turn, but which is also the reason of arterial cuts being so dangerous; for in such cases the wounded tube remains wide open; being held so by the stiffer inner coat; and thus the blood is allowed to run out indefinitely. Now this inner coat is wanting in the veins, whose walls sink in together when a cut is made in them, so that it is much easier to stop the flow of the blood in them.

Furthermore, the veins are furnished inside at intervals with little doors, similar to those we noticed at the entrance of the *auricles* and *ventricles* of the heart. You remember those important *valvelets*, on which depends so much of the mechanism; which permit the blood to pass in one direction, but will not allow it to return back in the other?—well, the little doors of the veins, which are also called *valvelets*, do exactly the same work. They open in the direction of the heart, to allow the blood to pass on, but it finds them fast closed if it wants to go back ; so that as soon as it has forced one passage there is no longer any hope of its return, and thus by degrees it gets nearer and nearer to the heart without any possibility of escape. There is nothing similar to this in the arteries, which the blood traverses in a single bound from the impetus it receives from the heart.

Finally—and this is most important—the blood which is found in the veins is no longer the same as that which fills the heart.

No longer the same ? you exclaim—have we then two sorts of blood in our bodies ? Most certainly, my dear child ; but you would not have suspected it ; for when you accidentally prick or cut yourself, or when your nose bleeds, it is always the same sort of blood that comes out—that fine red liquid which everybody knows so well by sight. This is because the blood flows at once from the small arteries and small veins, and what you see is a mixture of the two. The same mixture issues from all wounds, whether small or great, and on this account people are unanimous in declaring that blood is red ; a statement which is not true of either arterial or venous blood, separately. The last is black, as you might convince yourself if you had courage enough, and should happen to be in the room with any one who was going to be bled,—a rare event, happily, in these enlightened days.

In such a case it is always a vein which is opened, the reason of which you will understand, after what I said of the danger of cutting the arteries. You would therefore see a reddish black jet of liquid spout from under the lancet ; much blacker than red, however—that is *venous* blood. When, on the other hand, an artery has been accidentally cut, what comes out is quite different. It is a rosy, frothy fluid, almost like milk and carmine dissolved in it, which has been whipped up with a stick; this is called *arterial* blood.

Nothing is more simple, as you perceive, than to distinguish an artery from a vein; you have only to ascertain what is inside of it. When the blood goes out to our organs to nourish them, it is *arterial;* when it is returning back after having nourished them, it has become *venous*. But what—you will ask—is it going to do now at the heart, towards which it is on its road? It is going to seek there a fresh impetus which shall send it once more into the lungs, where it will again become *arterial, i. e.* and once more capable of affording nourishment to the organs. Therein lies the whole secret, and the why and the wherefore of the CIRCULATION.

This is easily said, dear child; but suppose that you do not comprehend it? Well, you need not be ashamed. There is no possibility of comprehending it until one has learnt what RESPIRATION is—so here we are stopped short.

To-morrow, then, when we will begin with the study of this third part of the History of Nutrition; and if the first two have amused you, I feel pretty sure you will not find this last one dull.

LETTER XVIII.

ATMOSPHERIC PRESSURE.

When we have been laboring very hard, my dear child, and want to rest for a minute, we say, *Let us take breath;* because breathing is an action which takes place of itself, requiring neither effort nor attention on our part.

But, if it takes place of itself, it does not explain itself; consequently, when I say to you, *Now, let us take breath*, this is not a signal for my having a rest, for I have undertaken to explain Respiration to you.

If you were a German, I would remind you of what so often happens when you put a fork into a dish of sourkrout. You want to lay hold of a little bit merely, but the strips of cabbage-leaf are twisted one within the other, and hang together in spite of you, so that without intending it you get hold of a whole plateful at once.

Now this Respiration affair is something like the sourkrout story—begging your pardon for the comparison. I should have liked to give you only a small plateful —a child's plateful—of it; but I feel the explanations coming, hanging one upon the other; and, whether I will or no, I must treat you like a grown-up person, and we must give up for once the nice little doll's dinners with which we began.

In my opinion, you will lose nothing by the change if you will but pay attention; for about that soft little breath of yours, which is always coming and going over your pretty lips, there are many more things to be learnt than you have heard of yet. As I said just now, you will find you have got hold of a plateful all at once. A good appetite to you!

To prevent confusion we will divide the subject into two parts. I shall explain to you first, *How we breathe?*—a very curious question, as you will see. And afterwards we will examine, *Why we breathe?*—which is still more interesting.

First, I must tell you that air is heavy, and very heavy too; a thousand times more so than you may suppose. The air we breathe, through which we move backwards and forwards, that air is *some*thing, remember, although we do not see it; and when there is a wind, that is to say, when the air is in motion, like a stream of water running down a hill, we are forced to acknowledge its being something, for we see it throw down the largest trees and carry along the biggest ships. But without going so far out of the way for examples, try—you who run so well—to run for two minutes against a strong wind: and then you shall tell me whether the air is something or nothing. But if it be something it must have weight, for all substances have; paper as well as lead; with this sole difference, that the weight of lead is greater in proportion to its size than that of paper. Now a sheet of paper is very light, is it not? and you would be puzzled perhaps to say what it weighs. But many sheets of paper placed one upon the other, end by forming a thick book which has its undeniable weight; and if some one were to heap upon your head a pile of large books, like those you see on your papa's shelves, the end might be that you would be crushed to death.

In the same way, a small amount of air is by no means heavy; but you can conceive that a great quantity of it gathered together may end by weighing a great deal. Now get well into your head the fact, that we, here, on the surface of the earth, are at the bottom of an immense mass of air, extending to somewhere about forty or fifty miles above our heads. Let us say forty to make more sure, for learned men have not yet been able to calculate the precise height to a nicety; and for my own part, I think we have done wonders to get so near the mark even as this. But can you picture to yourself the distance which forty miles high really is? I will help you to form some idea.

One mile contains 5,280 feet, and your papa is six feet high. One mile high would therefore be 880 times as high as your papa, But this is a mere nothing—only one mile's height. In forty miles there would be no less than 211,200 feet; and setting papas aside, of whom it would take 35,200, one on the top of the other, to go so far into the sky, let us think of the height of the tallest buildings you know; church and cathedral towers for instance. Now the towers of many parish churches are 150 feet high; the towers of York Minister not 300. At that rate it would take 1,408 ordinary parish church-towers, or upwards of 704 York Minster towers, piled one above the other, to reach to the end of the forty miles of air above our heads. I leave you to judge what would be the weight of a mass of paper piled up as high as that. You may safely grant then, that this mass or pile, or if you like it better, this *column* of air (for that is the proper expression), must be of considerable weight; as is still further made certain by the fact of its having been weighed, so that I can even name the weight to you if you wish to hear it. Bear in mind too, that the weight of a column of air will be in proportion to its *superficial extent*—to its breadth and width, that is; for, as you may suppose, a column as large in extent as one of the towers of York Minster will weigh a good deal more than one the size of a single brick.

But wait; here is a book on the table which will serve me for a measure, and as you will probably find the same on your mamma's table, you can follow my measurement. It is a French Grammar. The back is seven inches long and four and a quarter wide. That is, there are four and a quarter rows, each seven inches long. In other words, the back contains nearly—and let us call it quite, for convenience' sake—thirty inches side by side. Thirty *square inches* as it is called. Measure your mamma's copy and you will see. Now, can you guess the weight of the column of air forty miles high which this volume supports? Upwards of four cwt.; 450 lbs., that is to say. If you want to be very exact, here is the rule. Air presses on all bodies at the rate of fifteen pounds to every square inch; so now you can make the calculation for yourself.

But I suspect you had no idea you were so strong; for I see you tossing up the book, heavily laden as it is, like a feather.

Comfort yourself. There is no magic in the matter. If a very strong man were to push you on one side, could you resist him? Certainly not. But if another man of equal strength were to push you at the same time on the other side, what would happen? Well, you would remain quietly in your place, without troubling yourself more about one than the other, the two forces mutually destroying each other. And this is the case here. While the air above your book is weighing down upon it with a force of 450 lbs., the air below it pressss against it underneath with an equal weight, and this destroys the effect of the other. From 450 lbs. take 450 lbs., and nothing remains. Your grammar has nothing to carry after all, and you may toss it about as you please, without deserving much credit for the effort.

"What are you telling me?" you inquire. "If I put a stone on the top of my head, I can feel its weight easily enough; but if I put my hand on the top of the stone I no longer feel anything. How can the air below the stone press against it? And talking of columns—how pleasant it would be, for instance, if the people who go up the Monument were to have the weight of it on their heads when they get to the top!"

Well said, little one. And your objection reminds me of an argument which distracted my head as a lad, when I first heard the pressure of air explained by a good fellow who did not trouble himself to be quite as exact as you and I are in our discussions. I was told that the surface of the body, or the skin of a large man, measured sixteen feet square, which is equal to the surface of a table four feet long and four broad. Now, you know that in four feet there are forty-eight inches, and on the surface of the table are forty-eight rows, with forty-eight inches in each, or 2,304 square inches; so that a man's surface is 2,304 square inches, and the weight his body supports is 34,560 lbs., or upwards of fifteen tons—always at the rate of fifteen pounds to every square inch, you understand. Now, I was constantly asking myself how it happened that in entering a house one never seemed to get rid of this almost fabulous weight, since the roof of the house must naturally interpose itself between the air-column of forty miles high and the man who would then only have some few feet of air above his head. The roof would support the rest, that was clear. From whence, then, came the 34,560 lbs. which seemed to weigh as heavily as before; since, whether on the threshold of the door, while still under shelter of the roof, or two steps outside in the open air, under the tremendous column forty miles high, one never felt a bit lighter, not even to the extent of the weight of a single sheet of paper? This was a difficulty from which I could never extricate myself.

I found out the answer to the riddle afterwards, and a very simple one it is.

Air does not, in point of fact, *weigh down* like a solid fifty pounds' weight, which has no impulse but to descend, and has nothing to do with anything above it. It *presses against* rather, like a spring, which, having been compressed, tries to resume its natural position with a force equal to that which holds it back. Ask some one to show you the spring of a watch, and you will understand this better. Each atom of air is a spring of matchless elasticity, which nothing can break, which never wears out, which one can always compress, if one employs force sufficient, and which is always ready to expand indefinitely, in proportion as the compressing power is withdrawn.

Now, consider the column of air outside the door, where there is a pile of such springs forty miles high. The lower ones have to bear up all their comrades, which press upon them with their united weight, and these make desperate efforts to repulse the tremendous pressure, and to spread out in their turn. They endeavor to escape in every direction—to the right, to the left, above, below; but caught between the earth, which will not give way, and the compact mass of all the columns of air which surrounds the earth in every direction, and of which the lower part is equally compressed everywhere, they struggle unceasingly, but in vain; indefatigable, but powerless. You live in the midst of those little wrestlers, and naturally bear the punishment of the injury done to them. They press against you as against every thing else—before, behind, on all sides—with a force equal to that with which they are themselves compressed, or I would say, equal to the weight by which they are so horribly squeezed and contracted: so that, in fact, you bear this weight not only on your head and shoulders, as you might at first suppose, but also all along your body and limbs, under your arms, under your chin, in the hollow of your nostrils, everywhere.

Now we will suppose you to enter the house; and what do you find there? Outer air, which on its part has got in by the door, the window, and every little crevice in the wall. The column outside the roof no longer presses upon it, but what is the gain of that?

It was compressed when it got in, and the little springs will struggle as a matter of course, quite as much on this side of the door as on the other. The protecting roof has so little power that were it not itself protected by the air outside, the pressure of which keeps it in its place, the air within would shiver it into a thousand fragments in its efforts to get loose.

You laugh; but wait till I explain myself further. I will take the case of a miniature house to make the matter pleasanter to you; one fifteen feet long, fifteen feet wide, and with a flat roof, the most economical plan as regards space. Fifteen feet are five yards, and as the multiplication table tells us that five times five make twenty-five, our roof will in this case be twenty-five square yards (*i. e.* 225 square feet) in superficial extent, or *area*; it is not much, and you will find few as small.

Would you like to calculate the force with which the millions and thousand millions of little spring imps imprisoned under that poor unfortunate roof would press against it? We settled before that the quantity of them brought to bear upon a square inch had the power to push at the rate of fifteen pounds. Were they to push against a square yard (a surface 1296 times greater than the square inch) it would therefore be 19,440 lbs. This being so for one square yard, calculate for twenty-five square yards, and you will have the amount of pressure against our roof —viz. 486,000 lbs—merely that! And now tell me what cottage roof in the world was ever built so as to be able to stand against such a weight?

Perhaps though, you can scarcely appreciate the amount of heaviness, 486,000 lbs. Well, 486,000 lbs. is nearly 217 tons; and one of those railway trucks that you see laden with coals at the stations can carry, perhaps, from eight to ten tons, without breaking down. Say ten tons as an outside estimate, and then think of piling the contents of twenty-one such trucks on your roof, and yet you would still be short of the weight of air which is bearing down upon it. I need scarcely say now that were you to take away the air from within the roof, the air without would smash both it and the whole cottage flat, as a giant at a fair strikes an egg flat with one blow of his fist. To show you how in another way: take a moderate sized column or pillar, such as you see sometimes in a nobleman's grounds, of about the weight of the twenty-one tons, and set it up like a chimney on the roof of our cottage, then walk away to a little distance and watch what will happen!

There, little Miss Laugher! have you at last learned to value the weight of the air, or *atmospheric pressure* as it is more properly called; since it is the force with which the atmosphere presses against rather than weighs upon everything on the surface of the globe? It is no joke, as you perceive, and it affords plenty of subject for reflection. I have still to prove to you that I have not been making fun of you with my calculations, and that the weight of air upon a square inch is really what I have said—viz., fifteen pounds.

Now, there is a very simple way by which we might get to know your strength, and tell its amount in figures, if one chose; namely, by putting a weight on your arms —a heap of books, if you please—and keep adding and adding to it, until those poor little arms were unable to bear any more. Then weighing what they had borne, whether we should find it to be ten or thirty pounds—I cannot guess how much it might be at this distance— one might safely say, without fear of mistake, "The strength of this young lady is equal to ten, twenty, or thirty pounds"—in other words, "she represents a weight of ten, twenty, or thirty pounds" and by a similar plan people have ascertained the strength of the air—that is, the weight which it represents. They have weighed what it is capable of carrying.

I told you lately that the whole surface of the earth was covered by an immense army of little imps—otherwise called little air-springs, which, compressed by the giant mass of their comrades above, all of whom they have to carry on their backs, are always trying to protect themselves, by pushing back everything which comes across them. Imagine the bottom of a well. Our imps are permanently installed there as a matter of course, and face to face with the water they push against it, each one doing his best, on all points at once. As the pressure is equal everywhere therefore, and always the same, there are no signs of it to be seen.

Now insert in the water the end of a tube closed below by a cork which exactly fits the interior, but which can be moved up and down in the tube by means of a bar of iron or wood which runs through it. This is called a *piston*, I may as well tell you as we go on.

When the piston rises in the tube, it drives before it, as it goes, the air which was already there; and which cannot slip away down the sides because the piston fits so closely to them all the way along. The result of this is, that just underneath the piston there is a place in the water to which the air cannot reach, and at that place the water has no pressure upon it at all.

Now see what happens. Pressed upon heavily by the air in every other part and place, like a mouse hunted by a cat, who finds at last a hole through which to escape, the poor water darts at this and ascends the tube close after the piston.

So far so good; but if the tube is very long, and the piston rises rather high;—at thirty-three or thirty-four feet above the level of the water it has to continue its ascent alone. The water parts company, stopping quietly behind, half-way up the tube.

"What is the meaning of this?" you will ask.

It means that the force which presses on the well-water all round the tube, and thus drives it up, has done all it can, and that our little air-imps refuse to supply any more. The water which rises in the tube has a weight of its own of course, and with this weight it presses, as it is fair it should, on the water below. In proportion as the piston rises, the column of water which follows it gets bigger and bigger, and naturally its weight increases at the same time. At last there comes a moment when this weight becomes such that its pressure on the water below is equal to that with which the air-imps are pressing on the water in the well. Thenceforth they may push as they please ; no more water will go up. They are in the same position now that they were before, when their comrades (afterwards driven out by the piston) were pressing upon the same point, which had only a moment's freedom ; and this water column of thirty-three or thirty-four feet holds them in check, to exactly the same extent as the gay fellows whose place it has taken.

Nothing is easier now than to calculate, even to a few grains almost, the force of the pressure of air. One can get at the weight of water, thank goodness ! and it has been ascertained that our water-column will weigh fifteen pounds if the tube is a square inch in size. You will comprehend after this that it might be any size you may please to imagine, without there being the slightest alteration in the height of the column. The larger it is, the heavier will be the column of water on the one hand ; but on the other, the greater will be the number of air-imps turned out ; so it comes to the same thing in the end.

If you should feel any doubt about the correctness of this reasoning, you have only to try the experiment over again, in a well, filled with mercury for instance. Ask to be shown some pure mercury, which is also called *Quicksilver*, because one wants to express melted silver, apt to be constantly on the move ; it is often to be met with in houses. Mercury weighs thirteen and a half times more than water : according to our calculations, therefore, it would take thirteen and a half times less of it than of water to bring our little air-imps to reason. And this is just what you will find happens ; you will see the column of mercury stop short exactly at the moment when it has attained the orthodox weight of fifteen pounds; that is to say, at a height of twenty eight inches.

On the other hand, take some ether. You know that delicate spirit, which smells so strong, which makes your hand feel cold if it is put upon it, and which we give to sick people to inhale. Ether weighs one-quarter less than water. In a well of ether you would therefore see something quite different, and your column would rise without being asked, to something like forty-three feet, exactly up to the point of weighing—like the others—fifteen pounds to every square inch. Air will not be replaced with less.

That, then, is the measure of its strength, or our scales are deceitful.

LETTER XIX.

THE ACTION OF THE LUNGS.

I HOPE I have told you enough, my dear child, to enable you fully to estimate the force with which air presses upon everything on the surface of the earth, and consequently upon our own bodies among the rest.

If you understand this, nothing is easier than to understand how air comes and goes in our lungs.

When the cook wants to light her fire with two or three hot coals, what does she do?

She takes the bellows and blows it, does she not?

But if she has no bellows at hand, what does she do? You answer at once, she blows it herself with all the strength of her lungs.

By which it would seem—does it not?—that we are a sort of living bellows, being able, in case of necessity, to act as a substitute for the wood and leather ones of common use. And if we really possess the power of doing the work of a bellows, may not this be because we have within us some little machine of the nature of a bellows?

Exactly; and this fact gives me the opportunity of making you understand the action of the lungs by explaining that of the bellows, which is in everybody's hands, but which three-fourths of the people use, without troubling themselves to inquire how it is made or acts.

A bellows, as you know, is composed of two pieces of board, capable of being separated and brought together again at will, and united by a piece of leather so shaped and arranged that it doubles up when the boards close, the intermediate space forming a firmly-closed box, the size of which increases or diminishes at every movement of the boards.

We take the bellows down to use it, and there are the boards, lying flat upon each other, the box between them quite small. Is there anything inside, do you think?

"Nothing," you answer; "the bellows is empty."

Do you think so really, my child? Do you think a tumbler is empty, then, when you have drunk out its contents; and that jelly pots are empty when all the jelly is eaten? There are not so many empty things in the world, I assure you, as you suppose. You forget the air—that monster who is always wanting to stretch himself out, and pushes against everything he meets. He is an unceremonious gentleman, who takes possession of every vacant place; as fast as you put a spoonful on your plate, he takes up the room of the jelly which has been removed, and at each mouthful you swallow, he slips into the place of the water which goes away. When you think the glass and pot are empty, they are, in reality, full of air. You cannot see it; but it is there, you may rely upon it.

There is air, then, in the bellows-box, because there is air in every place where there is nothing else to dispute possession with it. The quantity is small in this case, no doubt, because the box is small and cannot hold much.

But now, look! I separate the boards, and the box, which was small, becomes large. For once, then, here is a box which must be partially empty; for it has just, as if by magic, made a space in itself in which positively there cannot be anything, since there was nothing there beforehand.

Ay! but look down at the centre of the upper board. You see a little hole there, do you not, and below the little hole a small piece of leather, which seems to close it up? That is a *valve*, one of those doors, such as we noticed before in the heart, and such as are to be found, moreover, in most houses, which let people through on one side but not on the other. This one opens when it is pushed from without, but lets nothing out which has once got in. Now, the air outside, as I said before, is always pushing against everything. He pushes as a matter of course, therefore, against the valve, and as there is nothing behind it to resist the pressure, in proportion as room is made inside the box, he enters and fills it with himself.

But presently some one begins to close the bellows, and he finds himself caught between the boards; on which these invite him to begone, with the same sort of politeness displayed by the police, when the hour of departure comes in a place of public exhibition; when, *i.e.*, they spread out on all sides, and force the crowd before them till they have found the road to the door. But the air cannot get back by the way it came in, the door being shut. As, however, it must go out somewhere, whether it likes it or not, it passes through the tube at the end of the box (the *nozzle* of the bellows), and comes out thence with a rush upon the fire.

When it is once gone the bellows can be distended again, and the process be repeated as before indefinitely.

And this is just what goes on inside ourselves. Your chest, my child, is a box which expands and contracts alternately; making a place for the air by the first effort, and then driving it out by the second. It is neither more nor less than a bellows, but of a simpler construction than that used by the cook. The exit pipe serves also for a door of entrance, and there is but one board instead of two.

The *exit pipe* is the *larynx*, of which we spoke before, when we were talking of swallowing the wrong way, and which communicates with the air outside, through the nose and mouth at the same time, allowing us to breathe through either one or the other as we like.

As to the *board*, I said a few words about it when I was describing the liver. It is the *diaphragm* — that separating partition—that floor which is placed between the two stories or divisions of the body—the belly and the chest.

But here especially the infinite superiority of the works of God over the miserable inventions of man comes out in all its grandeur.

A bellows which was to have the honor of keeping up within us that miraculous fire—the pre-eminently sacred fire—which we call Life, required something more than a common board for its foundation. And accordingly this, of which I am now going to give you a detailed history, is as marvellous as it is admirable. I fancy that when you have read my account, you will no longer turn up your nose at the vile word *diaphragm*.

Let us first take a peep at the construction of the bellows.

On each side of the *vertebral column*, from the neck to the loins, spring twelve long bones, one below the other, bent in the form of bows; these are called the *ribs*. The first seven pairs of ribs rest, and as it were, unite, in front, upon a bone called the *sternum*, which you can trace with your finger down to the pit of the stomach, at which point the finger sinks in, for there is no more *sternum*, and the last five ribs on each side no longer unite with those of the opposite one. For which reason they are called *false ribs*. On the other hand they are joined to each other at the ends by means of a strip or band of a substance sufficiently strong, but at the same time flexible, and somewhat elastic, which is called *cartilage* or *gristle*. The next time you see a roasting piece of veal on the table, look well at it, and you will see at the end a white substance which crackles under your teeth; that is *gristle*.

This forms the framework of our bellows, which you may picture to yourself as a kind of cage, widening towards the bottom and going to a point at the top, for the arches formed by the upper ribs are smaller than the others. The whole terminates in a sort of ring, through which pass, together, the *œsophagus* and the *trachea*.

The space between the ribs is occupied by muscles which reach from one to the other, and the whole framework or cage is shut in below by the *diaphragm*, that marvellous board whose history I have promised to relate.

The *diaphragm*, as I told you some time ago, is a large muscle, thin and flat, stretched like a cloth between the chest and the *abdomen*. It is fastened by an infinity of little threads called *fibres*, to the lower edge of the cage I have just been describing, and it looks at first sight as if it must be incapable of moving, since it is fixed in one invariable manner all round the body.

It moves nevertheless, but not in the same way as the boards of our bellows.

Ask your brother to hold two corners of your pocket-handkerchief; take hold of the other two yourself, and turn the handkerchief so as to face the wind. The four corners remain in their place, do they not? but the middle, inflated by the wind, curves and swells out in front like a ship's sail, which itself is only an immense handkerchief after all. Then draw the handkerchief tightly towards you, each to your own side, and it will recover itself and become flat again. Loosen it a little and it will curve and swell out again in the middle, and this manœuvre you can go through as often as you choose.

Which very manœuvre the *diaphragm* is continually performing, of and by itself.

In its natural position it bulges upwards in the middle, like a cloth swollen out by the wind, and thus occupies a portion of the chest at the expense of the lungs. When air has to be admitted, its *fibres* tighten and bring it flat again, as you and your brother brought the handkerchief flat just now by tightening it.

The whole space previously occupied by the arch of the *diaphragm* is thus given up to the lungs, which, being elastic, instantly stretch themselves out to it; while air, running in through the nose and mouth, fills up in proportion the empty place (*vacuum*) created by the extension of the lungs, exactly as in the case of the bellows.

But soon the fibres of the *diaphragm* relax. It rises up again into its old position, driving back the lungs as it does so; and the air finding there is now no room for it, goes out by the same way the other came in. I say *the other*, observe, because the air that goes out is no longer the same as when it came in; and this is the secret of *why we breathe;* while the up and down movement of the *diaphragm* is the explanation of *how we breathe.*

As you perceive, then, the mechanism of these bellows of ours, is of the most simple, and consequently of the most ingenious character, and leaves far behind it anything we have ever imagined.

Are you disappointed? Do you feel inclined to exclaim, "Is this all?" to ask where are the wonders I promised you? to protest that I may talk as I please about the inflating and flattening of a pocket-handkerchief? *you* can see nothing so marvellous in the matter; nothing worth making your mouth water for.

A little patience, Mademoiselle! Hitherto we have talked only of the machine; but there is a goblin inside it, and our fairy tale is going to begin again.

There are in some families certain old servants who belong to the house, more, it may be said, than their masters, in some ways. They educate the children, and they serve them till death; they live for them alone, and know so well what they have to do, both by day and night, that there is no need to give them any orders. Nay, not only is it unnecessary to give them directions—it is for the most part labor in vain. They are so completely at home in their business, that they will go nobody's way but their own. If you wish them to alter their habits they may obey you for an instant, but it is only to return into the old groove directly after; for they know better than you do what you want.

I was very little when I first read in the story-books of my day, some bitter complaints of the disappearance of this race of old-fashioned servants of the good old times. And you very likely may have seen it said that they are no longer to be met with. Yet there will always be some, depend upon it, in families, who know how to make and to keep them. Good old times or not, they have never been found in any other but these cases.

Still, *I* have just such a one as I have described—even I who am talking to you—and so has your mamma; and what is more, you have one yourself; and what is more still, everybody else has one. This servant of the good old times, who will never disappear (and this is more than one can promise of any other) is the *Diaphragm!*

When you came into the world, my dear child, and were merely a poor little lump of flesh, without strength, intelligence, or will; incapable of giving any orders whatever to those organs of yours, of whose existence you were not even aware, your *diaphragm* quietly began his duties, without leave or inquiry from you, and with your first *breath* your life began. Since which he has always gone on, whether you attended to him or not, and his last effort will be your last sigh.

When you go to sleep, careless of all that is to happen, until you awake again, that servant of yours, indefatigable at his post, labors for you still, and the light breath which half opens your rosy little lips as it passes through them; that light breath which your happy mother watches with such pleasure, is his work. Midnight strikes—one o'clock—two; all around you are buried in sleep—but he is awake still. Were it otherwise—were he to go to sleep when you do, you would never awake again!

This protector of each instant, this faithful guardian of your life, is, nevertheless, subject to you as a servant to his master. Attend to him, and he will obey your orders. You can make him go at a great pace, or slowly, as you choose; or stop him altogether, if the fancy takes you to do so: but this not for long. The servant of the good old times is obstinate in the performance of his duties. He will yield to you in trifles; but do not try to force him over serious matters. I have read somewhere of a desperate young fellow, chained down in a dungeon, who killed himself by holding his breath; but I never quite believed it. Mr. Diaphragm would not allow any one to carry rebellion so far as that.

But we have not finished yet, and you do not yet know how appropriate is the comparison I am making.

Should any misfortune, any grief, any trifling annoyance even, befall his master, a good servant suffers with him, and as much as he does; sometimes even more. Occasionally the master is comforted, while he remains still disturbed.

"And the diaphragm?" you ask.

The diaphragm does precisely the same, my dear child. Yours, especially, shares in all your griefs to such an extent that, truth to say, he is not always quite reasonable. The other day when your mamma did not want to take you into the country with her, he was so sorry for you that he went into perfect convulsions, and you sobbed and sobbed till she was obliged to say, "Come, then, you naughty child;" whereupon you embraced your mamma, and were quite happy again, while he remained still unappeased, and your poor little chest was shaken more than once afterwards by his last convulsions.

Sobbing, you must know, is merely a convulsion—a great shake of the diaphragm—which is the reason of its causing such a heaving of the chest.

It is the same with respect to joy. The joy of the master makes the servant dance, and so the diaphragm too! Its little internal jumps are, then, what we call laughter—a thing you are well acquainted with. Put your hand on your chest next time you laugh (and I hope it will be soon) and you will feel how it dances—thanks to the diaphragm which jumps for joy whenever it finds you in good humor.

Please to observe further, that nothing of all this is done to order. He starts of himself, poor fellow, without waiting to ask if you will ever know anything about it; and, in truth, you have known nothing about it up to the present moment.

What say you to the diaphragm now, my child? Does not the very name please you? You scarcely expected to find there—under your lungs—so good a servant, one so attached to your person, so strongly resembling in all points the best specimens we know among men. And still we have not done. I have reserved as a finale for you a new point of resemblance which will make you open your eyes very wide indeed.

The old servant is sometimes cross and grumbling. If anything is going against his grain in the house he has no scruple in saying so; and his mode of speaking is sometimes rather rude. Nor is it of any use to get impatient and impose silence on him; he will listen to nothing—it is his privilege. But let some unforeseen accident happen to his master, let him see him deeply affected, and in a moment all his anger is over. He sets himself silently to work again, recalled to order twenty times sooner by his master's emotion than by his utmost impatience.

You ask what I am coming to now? My dear child, what I have just told you is the history of the *hiccup*—the history of the hiccup, neither more nor less.

I must first tell you, however, that the *diaphragm* keeps up intimate relations with his neighbor below—the stomach. Every time he rises in the breast the stomach rises behind him; and not only the stomach, but also its companions, the intestines. All the officials employed in the business of digestion travel regularly with him; coming down as well as going up in company. Put your hand upon your abdomen and breathe strongly and you will feel the rebound of all the movements of the diaphragm.

Now, when matters are going on wrongly inside, when too much work has been imposed on the officials, or work they dislike, or else when they have been disturbed in their labors, it will sometimes happen that the *diaphragm* takes part with his comrades in the abdomen. He gets angry then, and shakes his master, who cannot help himself a bit. You must be very well acquainted with these attacks, which are very fatiguing when they last long. One begs pardon and resists him in vain ; he does as he pleases, without stopping to listen, turning everything upside down ; and do you know the only efficacious plan for calming him at once? It was a constant source of wonder to me when I was little. A sudden fright, a start unexpectedly caused by a friendly hand slipping secretly behind, and laying hold of one, was all-sufficient ; disarmed by the agitation you have undergone, the naughty, stubborn muscle forgives you, and you are cured.

Having dwelt so long on the truly wonderful resemblance between the proceedings of two sorts of beings, whom no one that I know of ever thought of comparing together before, I will now, my dear child, give you the key to all these comparisons, which seem so whimsical at first, but are so striking in reality, and which come to my pen of their own accord, as it were, in the midst of the explanations I have undertaken to give you. Many people who would not themselves care for them, will declare that they are too hard for a little girl to follow. But for my own part, I find that the eye can take in a mountain as easily as a fly, and that it is not more difficult to lay hold of great ideas than of little ones. It is short-sighted people, not children, who cannot see far before them. Who made the heavens and the earth? God, your catechism tells you. The same God made both; did he not? We do not acknowledge two. And if it be the self-same God who made everything, the hand of the universal Maker will be found everywhere; and from the highest to the lowest portion of His work the same mind will manifest itself under a thousand different forms. Not only, either, is each man separately, one by one, the work of God. The whole human race, taken in the mass, is also His creation; and the laws by which human society—that great body of the human race—seeks to regulate itself for the preservation of its existence, are undoubtedly the same as those which overruled the organization of our individual bodies. It is not very astonishing, then, if we find, in the life of human society around us, details corresponding with each detail of the life of the human body, or, at any rate, closely resembling them. What would really be astonishing, would be that mankind as a whole should be differently constituted from man as an individual, and that human society should have other appointed conditions of well-being than those of each of its members.

So, while I am on the subject, I should like to advise those who wish to apply themselves to what is called *politics*—that is to say, social life—to begin their studies of the body social, by studying the body human, first. They will learn more from it than from the newspapers!

But you have nothing to do with all this. For the present, take notice of one thing only; viz., that the hand of the same God has passed over everything, and that there is neither much presumption nor much merit in tracing points of comparison between the different parts of His work. These comparisons are not a mere play of the mind; they really exist ready made in the very foundations of things.

Now let us come down a little from these heights and return to our friends the lungs. I have not spoken about them for some time, and I have not yet told you how they are constructed.

I wish I could show you some, but the cook will do so if you would like to see them. The *lights* with which she feeds the cat and the dog are the lungs of some animal.

Take up a piece in your hand, and you will find you have got hold of something *light* (cooks have not given it its name without a reason), which is also soft, sinks under your finger if you press it, and rises again afterwards like a sponge. In fact, the lung, like the sponge, is composed of an infinity of minute cells, whose elastic sides can be contracted or expanded at will. They are like so many little chambers, into every one of which blood and air keep running hastily, each on its own side, to bid good day to each other, touch hands, and then hurry out as briskly as they came in. Whether the bit of lights the cat is eating, comes from an ox, a pig, or a sheep, you may look at it with perfect confidence; your own lung is precisely like it. You would see nothing different, could you look into your own chest.

So much for the *substance* of the lungs. As to SHAPE, imagine two large, elongated packets, flat inside, descending right and left, inside the breast, and bearing the heart, suspended between the two, in the middle. The extremity of each packet descends below the heart, and it is in the interval which separates them that the arch of the diaphragm performs its up and down movement.

I have already said that air reaches the lungs through the *larynx.* The *larynx* (of which we shall speak farther when I have explained another curious thing very valuable to little girls—the voice), the *larynx* is a tube composed of five pieces of *cartilage* (you know now what *cartilage* or *gristle* is), the firm resisting texture of which keeps it always open. After these five pieces of *cartilage*, come others, and the tube is continued ; but it then takes the name of the *trachea ;* the *larynx* and *trachea* constituting the *windpipe.*

At its entrance into the chest, the *trachea* divides into two branches, which are called *bronchial tubes*, and which run, one into the right lung, the other into the left. You sometimes hear people talking about *bronchitis.* It is an inflammation of these *bronchial tubes*, which are within an inch or two of the lungs. It is necessary, therefore, to be very careful in such circumstances, and do exactly what the doctor prescribes, because—one step further, and the inflammation extends from the bronchial tubes into the lungs themselves, with which it is not safe to play tricks.

Having reached the lungs, the *bronchial tubes* subdivide into branches, which ramify again in their turn like the boughs of a tree, and the whole ramification terminates in imperceptible little tubes, each of which comes out in one of those little chambers I was talking about just now. And this is the way in which air gets there at all.

The venous blood which leaves the heart, arrives on its side by one large canal, which passes out from the right ventricle, and which is called the *pulmonary artery.* And, to tell you the truth, while there is no learned man present to be angry with us, it is a very ill-chosen name, because it is *venous* blood which flows in this so-called *artery.* But the doctors have decided that all the vessels which run from the heart should be called *arteries*, and all those which go back to it *veins*, whatever may be the nature of the blood which they contain. We cannot help it, because they manage all these matters in their own way ; but in that case it was scarcely worth their while to talk about *arterial* and *venous* blood. It would have been better to have said simply, red blood and black blood.

Be this as it may, *venous blood* arrives from the right *ventricle* through the *pulmonary artery*. This divides itself, like the *bronchial tubes*, into thousands of little pipes, whose extremities come creeping along the partitions of the little chambers in question.

And here, then, takes place, between the air and the blood, that mysterious intercourse for the account of which I have kept you waiting so long ; and at the end of which the black blood becomes red, or, in other words, from venous becomes arterial. I have called it " intercourse," and this is really the proper phrase ; for this transformation of the blood is accomplished by means of an exchange. The air gives something to the blood, and the blood gives something to the air—each giving, in exchange, like two people over a bargain in the market-place.

With your permission, my dear child, we will stop here to-day. We have now got to the charcoal market, and it is a little black.

LETTER XX.

CARBON AND OXYGEN.

Here, then, my dear child, we have arrived at the explanation of that great mystery, WHY *we breathe.* Keep on the alert, for we are now entering into a region where everything will be new to you.

Here we are at the charcoal market, I said to you just now, and no doubt you concluded that I was beginning another comparison.

But no such thing ; there is no question of comparison or simile here ; I state the fact itself, pure and simple as it stands : it is a *market,* for commercial intercourse and exchange are carried on there, as I told you before, and it is a *charcoal* market, because *charcoal* is, positively, the essential and chief article of commerce.

You are astonished, I dare say, and are ready to ask me whether I can possibly mean real charcoal, charcoal such as the cook puts into the furnace. Surely, say you, we have nothing like *that* in our bodies? Surely we don't eat *that?*

But I answer yes ; real, true charcoal, and you do not dislike it ; you eat of it even daily ; nay, you do not swallow a single mouthful of food which does not contain its proportion of charcoal.

You laugh ; but wait a little and listen.

When you are toasting a slice of bread for breakfast, and hold it too near the fire, what happens to it?

It turns quite black, does it not?

When mutton-chops are left too long unturned on the gridiron, what happens to them?

They turn quite black also.

When your brother forgets the apples which he has set to roast, what happens to them?

They turn quite black, as you have seen more than once.

It is always black, then, that these things turn, is it not? and a fine rich *charcoaly* black, as you may see if you please to observe charcoal closely, for just such is the color of little burnt cakes, over-roasted chestnuts, and potatoes in their skins, which have been dropped into the fire.

But there is a common term by which we can express more accurately the misfortune which has befallen all these various things—slices of bread, mutton-chops, apples, cakes, chestnuts, potatoes, and what-not, when "burnt," "over-toasted," "over-roasted," or "over-baked." We may call them *carbonized*, or more simply *charred* or *charcoaled;* though the word *charred* is generally used only for burnt *wood*. But *carbon* being the principal ingredient of *charcoal*, and *charcoal* being one of the purer forms in which we get at *carbon*, they are almost synonymous terms, and you may call your burnt food *carbonized*, or *charred*, or *charcoaled*, whichever you prefer.

The next question is, how did charcoal or carbon get into the food so as to justify our talking of its being *carbonized* or *charred?* Even when we use charcoal stoves for cooking, the charcoal does not jump out and get into the mutton-chops, etc., you may be sure. Then it is clear it must have been in them before they were brought to the fire to be cooked; and such is indeed the case, only its black face escaped notice because it was in such gay-looking company, and kept itself hid behind the others like a needle lost in a match-box. Set fire to the matches, and you will soon have nothing left but the needle, which will then strike your eye at once. And so with our burnt food; the fire has carried off all the other ingredients, and the charcoal is left behind alone, exposed to everybody's view, as if on purpose to teach them that it was always there; in the apples, *i.e.*, the potatoes, mutton-chops, etc., which seemed so tempting when the black rogue was hid, but from which now, when he is there by himself, they turn away in disgust.

Charcoal is, in fact, a much more generally distributed substance than you have been used to suppose, dear child. That which comes from burnt wood is most easily observed, because there is a much larger proportion of charcoal in wood than anywhere else; but there is not a morsel, however small, of any animal or vegetable whatsoever, which does not contain charcoal. In the sugar which you crunch, in the wine which you drink, there is charcoal. I could even find some in the water you wash in if I were to try hard. There is charcoal in the goose-quill which I hold in my hand at this moment, and in the paper on which I am writing, and in the handkerchief on my knee. If I hold them all three in the light of my wax taper, I shall soon see them turn black and betray the presence of our friend. It exists in the wax taper itself, as also in the candle, as also in the oil lamp. If I were to hold a piece of flat glass above their flame, I should collect enough of it to blacken the tip of anybody's nose who presumed to doubt the fact. There is a portion of it in the air; a portion of it in the earth. Where is it not? In short, all the stones of all the buildings in the world are filled with it from top to bottom. *Charcoal*, under his more scientific and important name of *carbon*, may be called one of the great lords of the world. His domain is so extensive that one might go round the world without getting out of it; he is even worse than the Marquis of Carabas.

After this you will never, I hope, want to persuade me you do not eat charcoal; for, indeed, you would be puzzled to escape doing so. Of all the things you see on the dinner-table there is but one in which you will not find it—viz., the salt-cellar; and even while saying this, I mean only, in the *salt* itself, for as to the salt-cellar, clear and transparent as its glass may be, there is charcoal in it!

Our bodies, therefore, are full of charcoal. Everything that we eat supplies them with enormous quantities of it, which take up their quarters in every corner of our organs. It is one of the principal materials of the vast collection of structures of which I spoke to you in the early part of these letters, and of which the blood, the steward of the body, is the universal master-builder. If you remember, I told you then that these structures fell to pieces of themselves, in proportion as the workmen went on building, and that the blood, which brings fresh materials on its arrival from the lungs and heart, carries away the refuse ones on its return. And, of all these refuse materials, old charcoal is one of those which takes up the most room, as fresh charcoal took up a great deal of room in the new materials. The blood, as he goes back again, has his pockets quite crammed with it, and if he did not try hard to get rid of it as fast as possible, he would be disabled from being of any further use.

Now it is in the lungs that he clears himself of it. He gives it up to the air, which has need of it for a very interesting operation, of which I shall tell you more by and-bye; and in return the air gives him something which is quite indispensable to him, for without it he would not dare to return to the organs, as his authority would no longer be recognised.

In the same way, the charcoal-seller goes to market with his charcoal and receives silver in exchange.

If he were to go home without money his wife would receive him with abuse.

But what is the indispensable thing which the blood obtains in his marketing?

Remember its name well: it is OXYGEN.

And we must speak of it with respect, for we are talking here of a very great and powerful personage, very superior even to CARBON. If CARBON be one of the great lords of the world, OXYGEN is its king.

There is a certain substance, my dear child, of which many people, especially little girls, do not even know the name, but which yet constitutes of itself alone a good half of everything we are acquainted with in the world. And this substance is the very thing I have just named to you. It is OXYGEN.

Ascend into the air as high as you can go, viz., to forty miles or so from the ground, as we said before; *oxygen* forms the fifth part of that vast aerial ocean which surrounds the globe on every side. There it is free—is *itself*—if I may use the expression; it is in the condition of *gas;* that is to say, it eludes our sight, though there is no difficulty in ascertaining its presence, when one knows how to set about it.

Go down into the depths of the sea. People think they have good reasons for believing this to be two and a half miles deep on an average, which would give a pretty little sum total of tons for its whole weight, as you will be convinced, if you take the trouble of observing the space it covers on a map of the world;—to say nothing of lakes, rivers, streams, the water in the clouds, the water scattered throughout the interior or on the surface of continents, including that with which you wash your face every morning.

Oxygen enters in the proportion of eight-ninths into the composition of this incalculable mass. *Eight-ninths*, you understand, which is very near being the whole nine; in every nine pounds of water there are eight pounds of oxygen, the remainder being left for another substance, of which we shall have occasion to speak presently, and which is called *hydrogen.*

The earth on which you tread is full of oxygen. So far as we have penetrated hitherto into the interior of the globe, we have found king Oxygen everywhere: hidden under a thousand forms, connected with a heap of substances, not one of which could exist without him; imprisoned in a thousand combinations, and always ready to resume his natural condition if his prison-house be destroyed. The whole surface of the earth, plains, hills, mountains, towns, deserts, cultivated fields, everything you would look down upon, if on a clear day you could be carried high enough in a balloon to take in the whole earth at a glance:—all that may be considered as an immense reservoir of oxygen, out of which we should see it escaping in gigantic waves, if some superhuman chemist were to take it into his head to put our poor little globe into a retort of the same kind as chemists use among us. To give you an example; the stones of our fine buildings, in which we have already discovered the presence of *carbon*, are almost half made up of *oxygen.* In a stone which weighs 100 lbs. there are 48 lbs. of oxygen, and the first chemist who passes by could make them come out of it if he chose, if he were to use a little trouble and skill.

I enumerated to you last time many of the substances in which *carbon* is to be found; but as regards *oxygen* we must give up all attempt at making a list; it would comprehend the whole dictionary. Touch whatever lies under your hand—in your room—in the house—wherever you may go—I will almost defy you to put your finger upon anything—metals excepted—which is not crammed with oxygen. Your very body, to conclude with, would become so small a thing, were the oxygen it contains extracted from it, that you would be perfectly amazed.

So when I told you oxygen was king of the world, I did not say too much, did I? Between ourselves too, it is a great misfortune that people live on so complacently in total ignorance of this all-important material, which is connected with everything, which insinuates itself everywhere, which we make use of every instant of our lives, which may almost be said to be in some sort our very selves, since it constitutes three-fourths of our body, but whose name nevertheless would, I am certain, make many pretty little mouths pout, if one were to utter it in a drawing-room.

This is really the case. Many young ladies who are proud to know who Caractacus was, would be ashamed to know anything about oxygen. There is a foolish notion that women have no business with such subjects, probably because children are supposed not to breathe and mothers are not required to watch over them?

This reminds me that we are on the road to explain *respiration*, which I had almost forgotten in lifting up this corner of the veil behind which Nature hides her most valuable secrets from the idle and ignorant.

It is *oxygen* then, which the blood carries off trium phantly from his interview with the air in the cells of the lungs ; and, by the way, it is, thanks to this oxygen, that it returns from the lungs to the heart, and so from the heart to the organs, with that beautiful rosy tint which distinguishes *arterial* from *venous* blood.

Now the blood gives out this oxygen on its road every time it performs the journey, and the perpetual course it performs from the lungs to the organs, and from the organs to the lungs, has for its chief object the perpetual renovation of this previous provision, which is as perpetually consumed.

Do you ask of what use it is ? Does the blood leave it at random in our organs, and is it one of the materials with which our steward is constantly providing the little workmen of the body for their various constructions ?

No, my dear child. The proverb "*One cannot live upon air*," is a very true one, although it is equally true that we cannot live without air. Air does not nourish our organs ; on the contrary, it consumes them, and what we eat, serves to supply in precisely the same proportion its insatiable appetite. When we leave off eating, from whatever cause, the air does not leave off too. He goes on always just the same, and that is the reason why people who are starved to death are so thin. (The air has consumed the vital parts.)

You did not expect this ; but now prepare yourself to go on from one surprise to another. To begin with, I shall have to stop here and explain to you before we go any further—can you guess what ? Nay, I am sure you cannot ; FIRE.

There is not much connection, you will say, between *fire* and *breathing*.

But there you are mistaken. It is precisely the same thing, as I will prove to you next time.

LETTER XXI.

COMBUSTION.

Have you never, my dear child, whilst warming your little feet on the hearth in winter-time, asked yourself, *What is fire?* that great benefactor of man; fire, without which part of the world would be uninhabitable by us during at least a third of the year; fire, without which we could not bake a morsel of bread, and would have to eat our meat raw; fire, which lights up the night for us, and without which we should have to go to bed when the hens go to roost; fire, which subdues metals, and without which we should have neither iron, nor copper, nor silver, nor anything that is manufactured from those materials; fire, without which, in short, human industry could not rise to much higher results than that of the monkey and of the beaver?

We are all of us, it is true, so much accustomed to fire that we do not pay much attention to it, and have a sort of persuasion that lucifer matches have existed from all eternity. But the first men, who were nearer neighbors to that great discovery whence all others have originated—the first men treated fire with more respect than we do. It was to them one of the mighty things of the world. The ancient Persians made a god of it, and told how Zoroaster, their prophet, went to seek it in heaven, passing thither from the top of the Himalayas, the highest chain of mountains in the known world.

The old Greeks pretended that Prometheus stole it from the gods, to make a present of it to man, which came to nearly the same thing as the Persian account. The Romans had their *sacred fire*, which the celebrated Vestals were bound to keep lighted, on pain of death to whoever should let it go out. At the present day we do not stand upon such ceremonies, but warm our feet at it quite familiarly, without wishing for anything further. But you would see a terrible revolution in the world if some Prometheus reversed were, some fine morning, to steal it from us, and carry it back to its ancient owners. Every branch of human industry would suddenly stop, as if by enchantment, and in the course of a very few years the poor little framework of human society, of which we are now so proud, would totally change its aspect, and the whole world would be turned topsy-turvy.

But do not be alarmed; there is no danger of the sort. Fire is not a present once made to man, but liable to be taken away from him at will. It is a law of nature which existed before the human race came into being, and which will doubtless continue to exist when the human race shall have disappeared. The existence of fire is connected in the most intimate way with that of that great king of the world of whom we spoke last time—Oxygen. Fire is the wedding-feast of Oxygen with other substances!

When kings are married, what rejoicings there are! what a commotion! what illuminations! It is only right and proper, then, that the king of the world should have rejoicings and illuminations at his weddings also. And they have never been wanting. The rejoicings are the warmth which rejoices us; the illuminations, the flame which gives us light. But man, in his dealings with nature, is an imperious subject, such as few earthly kings are troubled with—happily for them! Whenever he wants warmth and light he forces the king of the world to get married, and then takes advantage of the feast; nothing worse than that.

"How so?" you exclaim. "If I want to make a fire with stones or iron, I should never succeed. Is this because oxygen never unites himself with those substances, nor with heaps of others which are equally useless in lighting a fire? Yet you told me that oxygen was to be met with almost everywhere."

It is a fair question, my dear child; but my answer is, that what you said last is precisely the reason why all substances are not fit for making fire of. When oxygen is already there, as he is in stones, for instance, the marriage is over—the feast cannot begin again. Kings are like other people in this respect; their weddings are only celebrated once. If you had happened to be present at the moment when oxygen was united to the materials of which stones are composed, you would have seen a feast of which I should like to have heard some news. I was not there myself either; but learned men in these latter days have succeeded in breaking the bonds which united oxygen with the primitive substances in certain fragments of stone, and with these substances thus freed, and consequently able to remarry, they have been enabled to give us, in miniature, the spectacle of the festivities of a fresh wedding. And I can assure you it is enough to make one shudder, to think of the time when such a marriage must have taken place on a large scale.

With regard to *iron* the case is quite different.

You have without doubt heard tell of Louis XIV. (of France), that proud king who was called *le Grand*, and who is said to have heard himself compared to the sun, without smiling. It seems that he one day took it into his head to marry, it is difficult to say why, with Madame de Maintenon, the old wife of a poor paralytic poet named Scarron, who, as such, however, was only known by some few farces. Do you suppose that the palace of Versailles was illuminated in honor of this marriage? Not a bit of it. It was a disgraceful marriage, which they were bound to keep secret. The ceremony was conducted mysteriously and without lighting a single candle more than ordinary.

I do not pretend to say that oxygen has any of these weaknesses, nor that he is any more partial to marrying with one body more than with another. In the good God's great world, outside of the family of man, they know nothing of our foolish pride, of our little weaknesses. It is nevertheless a fact that this dear monarch has his preferences, and that all his marriages are not made in this fashion.

Leave those pretty little scissors of yours, with which you would try in vain to make a fire, outside your window for two or three days, and then observe the dreadful, scaly, red stain which you are sure to find on them afterwards, and which is called *rust*. Have you any idea whence it proceeds? I will tell you. It comes from the oxygen, which has been making one of those cheerless secret marriages with the iron of your scissors. So there have been no pretty sights nor sounds, no lights nor cheerful noises to entertain anybody, and though people may have wished for them ever so much, they have had to do without them.

I will tell you the true reason of these marriages *incognito*. It is because oxygen is but feebly attracted by iron, who does not stand so high in his good graces as many other bodies, and so (to continue the joke) he unites slowly and languidly with him, as we may say.

Now tell me, when you set fire to a bit of paper, how long does it take to burn?

Half a minute, at the utmost, you answer.

Very good. And how long does it take to produce that rust-stain, even though it is probably not a hundredth part the size of the paper?

Two or three days, is your reply, for so I told you my self.

Here is a strange dfference indeed; but from it you may discover why you have not seen any signs of rejoicing or illuminations at the iron wedding. These are always in proportion to the quantity of oxygen which is being married at once—and this was—oh, such a slow affair! When the quantity is very small indeed, the festal illuminations are very small indeed too, and in fact escape observation altogether. In the same way that you would not be conscious of little bits of thread laid delicately one after another on your back, whereas you would plainly feel a large sheet, were it to fall on your shoulders. Yet what is the large sheet but a great quantity of little bits of thread? Only in that case they would all come upon you at once, like the marriage illuminations of burning paper.

Wait a little longer and we shall finish.

What is there, then, in the paper which pleases the oxygen so much that he unites himself to it so readily, and in such large quantities?

What is there? Two substances of high degree, who have actually risen to the dignity of a royal alliance, by the important part they play in the world; one of these, charcoal or *carbon*, we know quite well already; the other I have only mentioned to you in connection with water, HYDROGEN. Thanks to gas companies, everybody in these days knows *hydrogen*, at least by name. But before proceeding, I will just tell you that it is by far the lightest body that is known. It is forty and a half times lighter than air, which is not very heavy itself, although in the mass it has its weight, as we have seen.

The true province of hydrogen is water, where it keeps house with oxygen, in proportion of one to eight pounds, as you may remember I stated in my last letter. But beside this, *hydrogen* and *carbon* are in a manner inseparable friends, whom one invariably meets side by side in all animal and vegetable substances. In wood, coal, oil, tallow, and spirits of wine ; in everything in short that we call *combustibles*, because the name of *combustion* has been given to this marriage of oxygen with other bodies, hydrogen and carbon keep themselves shut up very discreetly and very quietly ; like two children playing at hide-and-seek. You have sometimes played at hide-and-seek yourself, no doubt? Now, if some naughty child had come behind you with a lighted candle, what would you have done? You would have had to turn out, whether you liked it or not, and be caught. Well ! this is what happens to our two friends, when you bring the paper to the fire. The heat forces them out, and the oxygen, which is always at hand, seizes upon them. In a twinkling they are married, and a beautiful flame springs up into the air, which lasts till everything has disappeared.

Hydrogen and carbon ! These, then, are the two great combustibles, the two parents of fire ; and as nature has lavished them upon us in what we may call inexhaustible quantities ; when you hear people lamenting and saying that wood is disappearing, that coal is diminishing, and that the human race will end by not knowing how to warm themselves, do not disturb yourself in the least.

There is more hydrogen in a bucket of water than is wanted to cook a large dinner. There is as much and more carbon in our stone quarries than in our coal pits, and when all the woods in the world are cut down (which I trust will never be!) do you know what we shall do? Why, we shall take to burning the mountains. The Jura mountains in Switzerland, for instance, (to take the most favorable case) are great masses of carbon, without its ever being visible. Everything depends upon knowing how to make it come out of its hiding place; but that will de done when it is wanted: more difficult matters have been accomplished already. As to oxygen, whether carbon comes to him from a log of wood or from a building stone; whether the hydrogen comes from a candle or a glass of water, is a matter of perfect indifference to him. He only considers persons, not their origin, and marries as willingly in one case as in the other.

So we have returned to the subject of *respiration*, on which I always seem to be turning my back; but now the question is, what brings us to it again? And this is the explanation.

When the oxygen picked up in the lungs by the blood has traveled with it to the organs, he finds there two well-known friends—hydrogen and carbon.

You smile, and exclaim at once, "Then he marries them, does he?"

Yes, my dear child; and it is only for that purpose he enters our bodies at all. And this is why I could not make you understand the nature of respiration until I had explained that of fire to you. As I have told you before, it is the same thing. Invite air into your body by the bellows of your chest, or drive it into the fire by the kitchen bellows—it is always king Oxygen whom you are sending to his wedding.

LETTER XXII.

ANIMAL HEAT.

Now, then, we have got hold of the secret of respiration; the *oxygen* within us unites itself to the *hydrogen* and *carbon*.

And for what purpose, do you suppose?

Unquestionably it must be to make a fire, since they never come together without doing so.

But what do people make fires for? I ask next. Well! surely to warm themselves, do they not?

And this is the history of your body being warm exactly like a dining-room stove, where the oxygen in the air forms an alliance with the hydrogen and carbon of the wood. Nature warms little girls inside, on precisely the same plan by which men warm their houses in winter.

Imagine, then, a little stove, furnished with little arms for helping itself out of the wood-basket as it is wanted, and with little legs to run and refill it when it is empty; the fire must be always burning there, and the stove must be always warm.

Just such a little stove is your body; your mouth being the little door, by which there constantly enter—not wood, that would hardly be pleasant—but—hydrogen and carbon under the forms of bread, mutton broth, cakes, sweetmeats, and all the good things people have learnt to make with sugar, fat, and flour. There is hydrogen and carbon in everything we eat, as I have already told you; but sugar, fat, flour, and *wine* are the substances which contain them in the greatest quantities, and consequently they are our best *combustibles*.

You are surprised, perhaps, at *wine* being a combustible; wine, which you think would put out rather than make a fire.

And it would. But that is only because in it, what is good for burning is mixed with a great deal of water, which prevents our being able to set it on fire. But if part of this water is withdrawn, you have *brandy*, which lights easily enough; and if part of the remaining water is withdrawn from the brandy, you have *spirits of wine*, which takes fire more easily still. If you have ever seen a *spirit-of-wine* lamp, you must know something about this. Judge from that what a fire spirits of wine must make in the body, even when it has a good deal of water with it; for it is right to tell you that your little stove is very superior to the one in the dining-room, and that it hunts out for consumption the smallest portions of combustible matter, in places where the other would be a good deal puzzled to find them.

This is not all, however. I have much greater wonders to tell you yet.

What should you say to a stove, which, summer or winter, night or day, in rain or sunshine, amid the ice of the pole, or under the sun of the equator, was able to keep itself constantly in the same condition; neither hotter nor colder one minute than another, whether you gave it much or little fuel, at a given moment, and sometimes when you gave it nothing for whole days together? It would be worthy of a fairy tale, would it not? Yet the human body is a stove of this description.

But this requires a little explanation.

It is rather bold in me, you may think, to assert so freely, that all the year round, from one end of the earth to the other, the human body is never colder nor hotter than mine is, for instance, at this present moment. "Hot" and "cold" is soon said, you argue: but the exact varieties of *more* or *less* are not so easy to measure, and especially not easy to remember, with reference to so many bodies, scattered over the face of the whole earth. What may be warmth for one in one case, may not be equal warmth for another; and even supposing that the same individual learned man could go and inspect every part of the globe in succession, how could he possibly recall, while touching the body of a negro in Senegal, in July, the exact amount of animal heat he had found in a Greenland Esquimaux in January?

Be content. I should not have settled the question so cavalierly, if people had not discovered an infallible method of estimating accurately, and always in the same manner, the degree of warmth, in other words, the *temperature* of the body.

Let us first see, then, what this method is, though it will oblige us to digress a little; but you are accustomed to that now, surely; and besides, if I were to go straight ahead, you would not be able to follow me.

Do you ever recollect being very cold? Let mammas look after their little girls as much as they please, to prevent it, it is sure to happen to every one some day or other. Now does it not seem at those times as if the whole body were contracting itself—and when people are shivering with cold, have they not a shrunk, shrivelled look? When the weather is very hot, on the contrary, our bodies feel as if they were swelling and stretching, and one seems to take up more room than before. This is the case with all bodies. Heat swells, or, as learned people call it, expands, them: cold shrinks or contracts them. Furthermore, *mercury* is one of the things most susceptible of this action of heat and cold, and we have had recourse to it accordingly, in the construction of the *thermometer*,* a very useful instrument, which you will hear spoken of all your life.

The *thermometer*, or *heat-measure*, consists of a little hollow ball filled with mercury, out of which rises a small tube of very thin glass, in which the mercury can move up and down. When the thermometer is exposed to heat, the heat causes the mercury to expand, so it goes up the tube; when the thermometer is exposed to cold, the mercury contracts and sinks again.

Now suppose you were to melt some ice in the palm of one hand, and try to dip a finger-tip of the other in a saucepan of boiling water; you would find a great difference of temperature between the two, would you not? Which difference of temperature people have succeeded in measuring with the thermometer, as accurately as your mamma measures a piece of cloth with her yard measure.

This is how it is done:

You surround the ball of mercury with pounded ice, and while it is melting make a mark at that point in the tube where the mercury has stopped in its descent. Then plunge the thermometer into boiling water. Whereupon the mercury goes up, up, up, till at last it reaches a point beyond which it will not pass. Here a second mark is made, and the space between the two marks is divided into a hundred perfectly equal parts, indicated by so many small lines, which are called *degrees*. But this word *degrees* has a double meaning in some languages. It means *steps* as well as the degrees of measurement we are talking about; steps being, as you know, the perfectly equal parts into which a staircase is divided. Fancy the mercury-tube a staircase, then, rising from the cellar where the melting ice is, up to the garret where the boiling water is, and let it consist of 100 steps. The mercury goes up and down this staircase, according as the temperature it encounters approaches that of the boiling water or of the melting ice; and if you wish to know exactly how far it is from the cellar or from the garret, you have only to count the *steps*. Hence arise those expressions which you so often hear—high temperature and low temperature. These mean, temperature according to which the mercury goes up or down this staircase.

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* *Thermometer* comes from two Greek words: *thermos*, heat; and *metron*, measure. The degrees in the Thermometer about to be described are marked on the *Centigrade* principle. [Not the one (Fahrenheit) in general use in the United States.]

On the actual floor of the cellar where the ice melts, there are yet no degrees (a floor is not a *step*, you know), so there you find the word *zero*, which means a cipher or nought. Then you begin to count 1, 2, 3, 4 degrees, marked by lines up to 100, where you reach the garret, *i.e.* the boiling-water height.

Of course, if the thermometer be exposed to an amount of cold greater than that of melting ice, the mercury will sink below the cellar. Accordingly the staircase is carried below it, with steps (so to speak) of precisely the same size as those above, and you count as before, 1, 2, 3, &c., as it descends; adding however, to distinguish these degrees from the others, "*below zero.*" You may go on in that way as far as 40; but there you must stop. At that point the mercury freezes. He sits down there on his last step, and will not go any further!

In the same way if the thermometer is exposed to a heat greater than that of boiling water, the mercury will rise higher than the garret. So the staircase is made to go up higher, and always with steps of the same size. counting from 101 upwards, as far as 350 if you choose; but no further, observe! If the temperature were raised beyond that, the mercury would begin to boil, and then, indeed, good-bye to steps and measured degrees! The gentleman would dance so fast that there would be no possibility of seeing anything, to say nothing of his flying away!

Now nothing is easier than to use the thermometer. You place it in the situation where you want to measure the heat, and the mercury goes up or down of itself until it reaches the degree which corresponds with the temperature of the place. It is much more convenient than your mamma's yard measure, which has to be moved about over the stuff, and which is very apt to slip if you do not hold it carefully. Dressmakers would be delighted to have a measure which only wanted laying upon the material, and which would unroll itself and stop short just at the proper point. And this kind of office the thermometer really performs.

We will suppose to-day to be the 30th of November. I have just carried the thermometer out of doors; the mercury has fixed itself at the second degree *below zero*. This tells me that it is freezing cold. My fingers have told me so already; but exactly to what extent they could not say. Just now in the room, the mercury was at the 15th degree *above* zero, thanks to the stove in which we have a good fire. In summer-time it rises to 25, 26, or 28 degrees. I once saw it climb as high as 33 degrees: in the shade of course, you understand; in the sun it would have been quite another affair. Well! there was a universal outcry against the heat. Grown-up young ladies whom I try to teach all sorts of things as I do you, pretended that it was impossible to work. Yet I should find a still greater heat inside my body, if I could get the thermometer there. Have no fears, however; I am not going to make a hole in it: luckily there is one already. I put the ball of mercury into my mouth. And now I can almost tell without looking. The mercury was on its way up the staircase as soon as I took the ball in my hand—and now it has reached the 37th step.

You can try the experiment on yourself, but I forewarn you that it ought to be rather hotter with you than with me: the mercury will probably rise a degree higher. I will not promise that in your grandpapa's mouth it may not sink a degree—but that will be all. In different mouths it has, between the 38th and 36th degree, room for the play of a little variation, but it can no more go beyond these than a tethered cow can get beyond the circle made by her cord as she turns round the stake. Go round the world with your thermometer, pop it into everybody's mouth, wiping it if you choose as you proceed, you will always find the mercury on guard. Its tethering cord is somewhat elastic, like everything else about us; but if by any accident it should exceed its limit by even one degree above or below, it would be quite as extraordinary as meeting a giant of eight feet, or a dwarf of three—which one does see occasionally, although the standard of human height varies generally round the centre of five feet.

Since there is a fire always kept burning within us, there is no difficulty in comprehending why our bodies always keep warm. Of course, however, the fire must be kept brighter in winter than in summer, but people have no need to be told so. Nature provides for the necessity. She gives us more appetite in cold than in hot weather; not that we can perceive much difference in ourselves in this respect from winter to summer ; for our bodies stick to their accustomed habits, and call out pretty loudly for the same daily rations, though without having the same need of them. In order to estimate fairly the connexion which exists between the internal need of food—*i. e.*, of combustible matter—and the external temperature, we must compare the Hindoo, who lives on a pinch of rice a day, between the tropic and the equator, with the Esquimaux, who, to keep up his 37 degrees of heat, beyond the polar circle, in a country where European travellers have seen mercury freeze, sometimes swallows from ten to fifteen pints of whale-oil at a sitting ! Just fancy *whale-oil !* which is much nastier than even cod-liver oil, if you ever tasted that ; but, on the other hand, it is a thorough *combustible*, and the poor people are not so very particular : come what will, the fire must be kept up, and that briskly. But without going thus into extremes, a friend of mine once told me that in Portugal, the land of oranges, it is not uncommon to see gentlemen and ladies (that is to say, those who can eat and drink what they please) dine standing, in five minutes, on a bit of bread and whatever else may be handy. Propose this system to the inhabitants of our colder and damper climate, whose very young ladies, fair and delicate-looking as they are, need a helping of good roast-beef for dinner to keep life in them, and they would only laugh at you. But those who were well instructed could go on to inform you that the chilly atmosphere of northern countries creates the necessity for a more active internal fire than is ever needed under the burning sun of Portugal, and that a mouthful of bread per day will not, in their case, suffice to maintain the appointed thirty-seven degrees of heat.

For the same reason, Spaniards drink water, and are satisfied; whereas English wine-merchants add brandy to a good many foreign wines, or they would be quite unacceptable from being deficient in *combustible.* It is for the same reason, also, that Russians can swallow, without wincing, bumpers of brandy which would kill a Provençal outright: and that the Swedish Government has no end of trouble to keep the country people from converting into brandy the corn that ought to go to the miller; whilst the Mohammedan Arabs accept without difficulty that precept of the Koran which forbids the use of wine and spirituous liquors. It is easy for the Arabs, who are kept warm by their climate, to do without brandy. It is less easy for the Swedes, who are surrounded by cold.

All this comes as a matter of course, and we do the same thing ourselves, without being unusually sagacious. In January, when the thermometer goes down to twelve or fifteen degrees below zero, I put more fuel into my stove than I am doing to-day, with only two degrees of cold to bear with. There is nothing surprising in all this.

The wonderful thing is, that when an Englishman goes to India, he takes his roast beef and his spirits with him, and in a temperature of more than thirty degrees of heat, quietly heaps up fuel in his stove, just as if he was in England, or nearly so. You think he will set fire to the house, perhaps. But no. Send the thermometer to his mouth for information, and it will only mark down thirty-seven degrees; neither more nor less than in the mouth of a rice-eater! The stove has more sense than its owner. It only burns just what hydrogen and carbon it wants, and takes no more trouble about the remainder than if it had not been eaten.

How about the remainder, then? you ask; if it is not consumed for use, what becomes of it? Do you remember, my dear child, that long ago, after explaining the office of the bile and the liver, I put off telling you what the bile *consisted of*, until we had talked about the lungs and respiration? Well, the time has come now; so listen.

The hydrogen and carbon which is not consumed by the oxygen in the blood, is seized upon by the liver, who employs it in the manufacture of bile. Therefore the greater the amount of unemployed hydrogen and carbon there is in the blood, the greater is the quantity of bile manufactured by the liver—that is all. When once the body has attained to its proper degree of heat, it is in vain you load it with combustibles; it will not get any warmer, do what you will. Only you will have cut out so much extra work for the liver, and the poor wretch will have to get through it as he can. Accordingly, what happens in the long run to our great eaters and drinkers, whether in India or elsewhere? The bile-manufacturer, overwhelmed with work, gets worn out at last, and kicks; and people come home with that miserable disease, which is called the "liver-complaint."

This is one explanation of that wonderful uniformity of temperature which, happily, human imprudence cannot disturb. But the blood has a second resource for getting rid of its superfluity of hydrogen and carbon, and herein especially is displayed the beautiful foresight with which everything about us has been prearranged. We are told that wolves, when they get hold of a larger piece of meat than they care to eat at the moment, carry off what they do not want to some corner and bury it in the ground, whence they get it again when their hunger returns. Dogs sometimes do the same; and the blood has a similar instinct. Listen attentively, for this is very interesting.

I light a candle and you see a bright flame, which will last as long as there is any tallow below the wick. Can you tell me what it proceeds from?

Nay, do not laugh at the question; it is quite to the purpose, I assure you.

We know, do we not, that the substances which burn best are those which are full of hydrogen and carbon? Tallow, then, is one of those substances. But tell me further, if you please, what is tallow?

Tallow is *mutton fat*, allow me to say, if you never heard it before.

Now comes the question, who provided the sheep's fat with such a quantity of hydrogen and carbon as to qualify it for making candles?

The sheep's blood undoubtedly, since blood is the purveyor-general of living bodies—of the sheep's body as well as of our own.

But how came it that the sheep's blood had so large a stock of these materials?

Undoubtedly, again, because there was more of them in the food the sheep had eaten than the oxygen was able to consume or the liver to employ. In short, the sheep has lungs and a bile-manufactory, as we have; oxygen performs the same office for it as for us. What takes place in its body in the matter of respiration is an exact counterpart of what happens in ours, and the history of its fat is simply the history of our own.

Now do you think it is for our sakes that the sheep's blood deposits its fat in little pellet-like morsels throughout the body; do you suppose the poor creature works in this manner merely to have the honor of providing us with candles? It is not likely. I was talking about the wolf just now; but there is no need to look beyond ourselves. In many poor people's cottages there is somewhere an old earthen pot in which the savings of each day are carefully put by, penny by penny, as a last resource in time of need. Should a wicked thief succeed in murdering the owner and laying hold of the treasure, he will squander in a few hours of brilliant revelry the precious hoard so slowly got together as a provision for possible needs. And this is what man does, when he kills the sheep and takes its fat to make candles of! The poor animal's blood knew well that bad times might come, that grass might fail, and the combustible matter conveyed into the body become insufficient to maintain its thirty-nine or forty degrees of heat (which is the sheep's measure, who is rather hotter than we are). So it quietly laid up its surplus stock of combustible so conveniently brought to hand, and destined to be burnt little by little in the depths of the organs, should times of scarcity arise. But here steps in man, the universal thief of Nature, and turns it into a beautiful flame, regardless of cost, and burns in one evening what his victim had been economizing for so long. To burn for burning's sake, however, has always been the fate of tallow, the only difference being in the way it is done. Like the poor man's clumsy pence, which were put by to be spent some day or other, only in another manner. It is worth noting here, that some of the Russian soldiers who were in France in 1815 had a very good idea of restoring candles to their original destiny. As children of the north, driven to get fire wherever they could, they ate all the candle-ends they could lay hold of, preferring to burn the tallow, sheep's fashion, inside rather than out!

Fat is, then, the savings' bank of the blood; there it deposits its savings, and there it can always find them again in time of need. Witness the fat pig described by Liebig, the great German chemist, which having been swallowed up by a landslip, was found alive at the end of 160 days. Fat was out of the question there, of course ; the animal weighed ten stone less than before. We will take the illustrious professor's word on trust, but were a few days subtracted from the account the case would still be a splendid example of the resource which blood finds in fat when other nourishment fails ; for the pig had certainly been breathing during the whole 160 days, and as, in all probability, he moved about much slower than usual, his hydrogen and carbon fire was never extinguished for a single instant ; of that I am perfectly certain, and you shall soon know why. It was well for the poor fellow himself that he had put by his provisions in time of plenty. And who suffered ? Why, the pig's master, who had looked forward with pleasure to the rashers of bacon he should cut by and by from the stores of combustibles in his larder. For once Master Piggy ate his own bacon himself!

You understand now, I hope, by what ingenious management that marvellous stove, called an animal, never burns too much fuel, whatever be the quantity it is supplied with, and how, on the other hand, it has always as much as it wants.

I have now to explain how important it is that it *should* always have enough, and that this is not merely a question of heat and cold, as with dining-room stoves, but one of life and death! Cheer up! I have only one more word to say about Respiration, and when you have heard it you will appreciate still better the lesson of economy which you have learnt from Nature to-day.

LETTER XXIII.

ACTION OF THE BLOOD UPON THE ORGANS.

The first time we talked about the Blood, my dear little pupil, I introduced him to you as the steward of your body, and what a steward to be sure! Always awake, as you may remember, always in motion; his pockets ever full of the materials unceasingly required by the indefatigable builders of that human edifice in which it has pleased God to house your dear little self. If you wish really to understand what follows now, we must carry on the simile a little further.

A steward not only provides the workmen with materials, but gives them orders as well, and this is part of the blood's business also. He is not only commissary-general, but *whipper-in* of the whole household, and besides the care of giving out all the stores, has the charge to see that everything is properly done. The unhappy men who purchase prosperity at the dreadful cost of maintaining slavery, pretend that their slaves would do no work worth looking at, were there not always some one behind them with a whip in his hand. Well, our organs are slaves, and slaves of the worst sort. They would never do anything at all, if the blood were not everlastingly whipping them up in his ceaseless rounds. Let him come to a stand-still for one minute, for a second even, and everything stops short; then we are at once in the castle of the Sleeping Beauty in the wood.

But perhaps I cannot do better than to compare our bodily machine to a violin—to hit upon something less dismal than slaves—a violin with blood for its bow. As long as the bow runs over the strings the violin makes music and lives; when the bow stops, it is silent and dies.

You have never yet had a fainting fit, my dear child; it rarely happens at your age. But you may possibly have seen somebody faint; or, at any rate, you have heard it talked about. Do you know what takes place in such cases? Now and then, in consequence of some violent emotion, but how or why I cannot tell you, all the blood rushes suddenly back towards the heart, as during an earthquake a river will sometimes flow back towards its source, leaving its bed dry. Thereupon the face turns white, as if to give notice that there is no longer anything red below the skin. The organs, no longer stimulated by the blood, leave off work altogether. The brain goes to sleep, the muscles relax, consciousness ceases, and you behold the poor body, from which the soul seems to have departed, give way on all sides, and fall to the ground like a corpse. This is not exactly death, but it is yet an interruption of life. It would be death if nature did not get the upper hand again, and send back the deserter to his post.

I may remark here that it was partly on this account that some of the ancients thought the soul was seated in the blood; not a bad idea for people who were determined to pronounce where the soul was, when it is so easy to say one knows nothing about it. But those who placed it in the breath, and who have bequeathed to us those beautiful expressions—*yielding up the last breath*—*giving up the ghost*—were not wrong neither.

In point of fact the blood is not the soul of the body;

in other words, does not keep the body alive, otherwise than by keeping up unceasingly and everywhere that magic fire of which we were talking last time.

The French people, in their picturesque language, have found an expression, full of energy, to express the action exercised by the master workman, who knows how to make his people work : "*Il vous met le feu sous le ventre.*"* This is, to the letter, the process employed by the blood to make the organs work. It makes a fire under the belly. Unhappily their work only lasts as long as the fire which causes the heat, and which is so necessary to life that it is almost confounded with it. It is the sacred fire of the Roman Vestals, which must be fed night and day under pain of death should it go out. Now, if to feed the sacred fire of life, it be necessary that the blood should everywhere find hydrogen and carbon *unattached*, that is to say, free and ready to unite themselves to oxygen, it is no less necessary that he should bring oxygen with him everywhere. Else there would be no marriage, and therefore no fire. Qxygen is, then, the talisman which brings the organs to obedience. Without oxygen he would be a slave driver without his whip ; his orders would be despised. If the organs were to be deluged with *venous* blood—with that black blood which has lost its oxygen, they would not stir any more than if they had received so much water. They acknowledge nothing but *arterial* blood—red blood—blood rich in oxygen. That is what they respect, and which has authority over them ; the other is a bankrupt who has lost his credit with his cash ; those whom he fed but lately now laugh in his face. And as our good steward spends all his oxygen every time he goes his rounds, it would soon be over with him, and, consequently, with us, too, if he had not some method of replenishing his purse after each journey. Happily the lungs are the inexhaustible chest to which he always returns to renew his right of authority; that is, his power of preserving life. When it comes to the *last sigh*, the last effort of the diaphragm by which the chest is closed forever, we must bid adieu to life. In yielding up that, we have in very truth yielded up the ghost.

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* Literally, *he puts fire under their bellies;* but here signifying that he makes it so hot that the organs are compelled to continue in motion.

This is no joke, as you see, and it would not do to be caught unprepared, with an inexorable necessity hanging over one, which never allows a moment's respite. The blood acts like a reasonable being, therefore, in laying up his stores of combustible in reserve. Moreover, whether he has done so or not, the fire must go on all the same; that is absolutely necessary; and if he has no spare fat to feed it with, when, from any cause, the stomach leaves off working, he makes use of anything he can lay his hands upon.

I know a story on this subject which will amuse you.

There lived, in the reign of Francis I. of France, an honest countryman, of Périgord, named Bernard Palissy. At that time everybody could not afford to have earthenware plates, as they have now. It was a manufacture of which only the Italians had the secret, and Bernard, who knew something of the matter, from being a glass-worker, took it into his head to try and find it out entirely by himself. So, without asking anybody's advice, he turned potter, built ovens, picked up wood as he could, manufactured his first pots, whether well or ill, made a beginning, and waited. He had fifteen or sixteen years of it before he succeeded; fifteen or sixteen years of ruinous experiments, which would have discouraged a less sturdy heart than his. But he, after he had succeeded in picking up some money by his church windows, returned to his work with unconquerable perseverance, insensible to poverty, deaf to the ridicule of neighbors, and unmoved by the abuse of his wife, who was furious, as you may suppose, at being forced to play the heroine without having the least turn for it. And one fine day there was a grand uproar in La Chapelle-Biron (that was the name of his village). "Bernard Palissy has gone mad," said everybody ; "he is burning up his house to bake his pots." And upon my word it was true! Wood happened to be wanting while a batch was in the oven, and Bernard having begun by using up the garden palisades, took next the large tables, and at last the floor of the house! What his wife had to say, I leave you to judge ; as for him he listened to nothing ; but, fixing his eyes on the insatiable furnace, threw in one thing after another, caring only for the risk to his handiwork. The ceiling would have followed the floor had not his pots been sufficiently baked without.

And thus, and thus, does the blood, when combustible matter fails him! He demolishes the house, and throws it, bit by bit, into the fire. The fat goes into it naturally enough, as I have already explained to you. It is the fuel-store of the house. It was put by on purpose, and may be used up without injury. Then comes the turn of the muscles ; more useful without being indispensable. Those are Bernard Palissy's palisades one may contrive to do without them. They melt away, so to speak, after a few days' fast, and you find yourself what people call "nothing but skin and bone." But then, if this condition is prolonged, and the exhausted flesh cannot supply the demand, the blood does not hesitate a moment. He boldly falls upon the most important organs, without stopping to consider ; he, too, is devoted solely to his work, and that, like the baking of pots, never comes to an end by being completed ; if external help does not arrive in time, the house soon becomes uninhabitable, and life slips away. The man dies of hunger.

But in the same way that poor Bernard Palissy was in reality working, all the time, for his wife and children, whose future well-being he strove for as the final end of all his efforts, though at the risk of letting them sleep under the bare heavens ; so the blood was laboring up to the last moment for that very life which he at last turned out of doors ; and the work of destruction which caused its final departure has had in reality the effect of prolonging its stay. Without it, all would have been over long before.

LETTER XXIV.

THE WORK OF THE ORGANS.

Thus much is settled, then. It is the blood which sets everything in motion throughout the body. The organs are idlers who would do nothing but for him; they only work when goaded on, if I may use the expression, by that fire—always on the point of going out—which he is perpetually coming back to rekindle, thanks to the oxygen he carries with him from the lungs.

This will enable me to explain many things, which, although not new to you, you have probably never tried to account for before.

To begin with: do you remember what happened to you the other day, when you tried to overtake your mischievous brother in running, and he, taking advantage of his school-boy legs, led you mercilessly through all the garden walks, without having the grace even to let you catch him at the end? You were quite out of breath; your heart beat so rapidly it almost hurt you; and you were so hot that the perspiration poured in great drops down your face, so that your mamma, quite frightened, took you up in her arms and carried you to the fire; for the coolness of evening was coming on, and a little girl drenched with perspiration is soon chilled.

Tell me now, what connection was there between your overrunning yourself in a race and the extraordinary degree of heat which came over you so soon? Your cheeks were cool and fresh when you began to run; what made them so red all at once, and especially at a moment when the air was cool and fresh in the garden?

You open your eyes in surprise; you had never thought of this. No! that is just the way with little girls. They run; they get hot; it seems as natural as warming oneself in the sun, and they never ask why it is so.

Yet you could almost tell me the "why" yourself, if you stopped to think about it, now that you are what your school-boy brother would say "*up to a thing or two*;" but to save time, I will help you.

You run as a bird flies, without thinking about it. Nevertheless, if you could see with a magic glass all that takes place in your body while those active little feet are carrying it like a feather across the garden, you would be perfectly amazed. One of these days, when we have finished our present history, I will tell you that other one, which is equally worth the trouble. It is enough for the present to know, that a very complicated piece of work is being carried on there, in which almost all the muscles of the body take part at the same time, contracting and relaxing in turn, like so many springs, of which each either drives forward or holds back a part of the machine. In fact, while your eyes and thoughts are fixed on the butterfly which is flitting away from you through the air, there is going on within you such an unheard-of outlay of efforts as could never be got out of our idlers if the terrible steward did not lash them severely.

Now, his lash, as we have said often enough, is that eternal fire, the materials of which he conveys to all parts of the body. On those special occasions, therefore, he is obliged to make his fire burn much more briskly than usual—exactly like railway engine-drivers, who increase the heat of their fire to get up steam in proportion to the speed they wish to go.

From this you will understand that it is no great wonder that your small frame should get heated from such work as racing and chasing ; and that if you pursue it too long, the perspiration which comes out all over you is sufficiently explained.

This is not all, however. The fire, whose strength has to be increased, naturally requires a larger amount of combustible matter than before, and forasmuch as there is only a certain fixed quantity in each drop of blood, whenever the muscles want more than usual, the blood itself must flow to them in greater abundance. Now if it were a question of supplying only one part of the body (as it is, you may remember, of supplying the stomach during the progress of digestion), he might contrive to accomplish his task there by neglecting it elsewhere, and overflow one organ at his ease, at the expense of all the rest. But in this case he is wanted everywhere in the same abundance. It is not a question of taking one muscle's share for the benefit of another. From one end of the body to the other, all want to be deluged at once. And remember that these exigencies do not bring a drop more blood into the body. How is he to get out of his difficulty then, this overwhelmed steward of ours ? Well ! just as your mamma manages, my dear, when there is more to do than usual in the house ;—by running quicker than ever from the cellar to the garret, and from your room to your papa's ! That is called doubling oneself ; and this gallant blood doubles itself to some purpose. He runs and runs and runs, arrives in hurried streams, and returns full gallop, passing and repassing through the heart, which empties and fills itself in sudden jerks. Unluckily, the poor heart is a delicate sort of person, who does not like having his habits disarranged, and this forced work soon makes him desperate. The other day, in his despair, he knocked with all his strength against the walls of his little chamber, to warn his young mistress that he could bear no more, and that they were both of them in danger. In fact, you ought to know that if one was infatuated enough to go on running too long, one might die of it. When you learn ancient history, you will probably be told of what happened to the soldier of Marathon, who flew like an arrow from the field of battle to the gates of Athens, that he might tell his fellow-citizens a quarter of an hour earlier, that his country was saved ; and he fell dead on his arrival.

But it is not the heart only which suffers by this mad career of the blood. During each journey it performs it passes through the lungs, which in their turn are forced to play with hasty jerks. And this is well for our good steward ; for the lungs, filling with air at each descent of the diaphragm (if you remember what we have said before), more air, and consequently more oxygen, comes in, and the blood has by this means a larger stock on hand, ready to help him out in the unusual waste which is just then going on in the muscles. I spoke just now of railway steam-engines. See how self-supporting ours is! The greater the amount of fire wanted, the faster the blood flows ; and the faster the blood flows, the oftener does the coffer re-fill itself, whence comes the supply of oxygen requisite for keeping up the fire. All this goes on at once, by one impulse, and the balance between the receipts and expenditure settles itself of its own accord. How thankful many families would be if their money-chest would but fill itself in the same way — in exact proportion as they spend the cash! There is only one slight drawback, which is, that the diaphragm gets tired with the unaccustomed gallop it is thus forced into. It falls into convulsions, therefore, like its neighbor the heart, and the breathing is stopped, from having been driven too rapidly. An excellent example for people who want to spend too much at once; showing that Nature herself cries out against it, even when the only thing wanted is atmospheric air.

Now, run if you dare! And, to tell you the truth, it would be a great pity if you did *not* dare; for our good God has made little children for running. They have nimbler blood than we older grandfathers, more elastic lungs, and consequently more oxygen to spend at a time. But you must confess that it is a great pity we should run all our lives as many people do, without having the slightest idea of these admirable contrivances, thanks to which we are enabled to do it. We can run all the same, it is true, without the knowledge, the little child as easily as the little roebuck, which sets a similar machine in motion. But it is no use talking about the little roebuck; it cannot learn what God has done for it, but the little child can, if he will.

Furthermore, there is nothing to be really alarmed about, for those great commotions only occur when we have committed excess; and it is a very good thing, in a general way, for the blood to give us a stroke of his lash from time to time. I told you lately that the fire which sets the organs to work is life; and it is no misfortune to be a little more alive than usual. Besides which, this increased activity of the internal fire does not serve us in running only. Every time that a man makes an effort; every time he lifts a weight, or handles a tool, the blood rushes forward to deluge the muscles that are thus called into play; the heart beats more quickly, and the air streams in greater abundance into the lungs. Look at a man chopping wood. If the log resists too much, if for a minute or two the man has to strike blow after blow without stopping, you will soon see him panting for breath, just as if he had been running a race. On the other hand, he will have gained something from chopping his log besides the right of warming himself before it at the fire. Blood does not carry fire only into the muscles; he supplies them with nourishment also, does he not? Every drop of blood deposits its little offering as it goes by, and consequently the greater the number that pass along, the richer is the harvest for the muscle. Look, accordingly, at the laboring classes. How much healthier and stronger they are than those who do not work! I speak, of course, of working with one's limbs generally; for those poor girls who work from morning to night, sitting on their chairs, are none the better for it, but, on the contrary, worse. There are also certain worthy fellows who, like myself at the present moment, drive a pen over sheets of paper for half a day at a time, whose muscles never get any bigger for it, that is quite clear. Moreover, one condition has to be fulfilled, which unhappily is not always done. The more people labor, the more they ought to eat. To you, who have just been looking at the drama that is performed in the body every time a muscle is set in motion, this is obvious enough. There is no fire without smoke, says the proverb. It would have been much better to have said,—there is no fire without fuel;—and the fuel for our fire is, as you know, what we eat. Try if you can get one stove to burn more brightly than another, if you have put less fuel into it. Yet, alas! this is what many poor wretches are obliged to do but too often; and then the blood, instead of feeding their muscles, consumes them, for the reasons I gave, in telling you the story of Bernard Palissy. Think of this, oh my dear child, when you are grown up, and never grudge those who work for you their proper share of food.

Here I see many other lessons crowding up, out of what you have just learnt.

And first Nature herself, taken as you find her, shows you that manual labor is, for us, a most beneficial condition of existence; that it brings about a re-doubling, an exaltation of life; and that consequently, we have no need to look down upon those who gain their bread, as we word it, by the sweat of their brows. I told you this before, in speaking of the hand, which is of so much more use to those people than to you; and I repeat it now for another reason, viz.: because labor elevates him who undertakes it, and creates a real physical nobility. Barbarians in old times, who knew nothing noble nor grand but war, despised labor, and left it to their slaves; so much so, that the name *servile labor*, *i.e.* the labor of slaves, has stuck to it in some places. As for war, the lot of the ancient nobility, I scarcely dare to say much against it, however much I should like to do so on some accounts. For, after all, so long as there are ruffians to trample on the weak, one is only too glad to find brave men ready to risk their lives in keeping such rascals down: so long as there are wolves, we must needs keep shepherds' dogs. But in spite of everything, the best that can be said in favor of war is, that it remains a sad but inevitable necessity, and that to get rid of it, more is wanting than the wish. What a contrast to labor—that contest of Man with Nature;—that merciful and fruitful war, where victories are not estimated like other victories, by the number of the slain, but which, on the contrary, scatters fresh life around it as it spreads; fresh life in the laborer himself, by the very act of work, fresh life around him without, by the fruits that work produces!

Between the man who dies in slaying others, and the man who keeps others alive by living longer himself, it seems cruel to make invidious comparisons; but if it be just to honor the first out of respect for the cause he has defended, whenever that cause is respectable—it is, to say the least of it, not less just to do equal honor to the second.

But let us come down from these philosophic heights, and return to you, dear child; to you, who have nothing to do with war, its massacres or its laurels.

It is true, however, that you have nothing to do either, with chopping wood, and I am not asking you to undertake any such thing. But in the life of a woman, from the time of her childhood upwards, a thousand things arise for the hands to do, and the question is, how often you are likely to feel ashamed of not sending for the servants to do them? Avoid this false and fatal idea as much as possible. The work of the hands dishonors no one; it is honorable. To cast it aside altogether is to make yourself smaller instead of greater; to deprive yourself of one of the glories and the joys of life. If a good thing is set before you at dinner, do you send for the servants to eat it? If an occasion arises for making the blood circulate more rapidly in your veins, and of increasing the strength and life within you into the bargain, why make *them* a present of it? Especially when it cannot be an agreeable present considering that good servants have plenty of such opportunities from morning to night every day.

There was once upon a time a Persian prince staying in Paris, who was taken to a very fashionable ball, that he might see a specimen of European civilization. I am not talking about a prince in the "Arabian Nights;" mine lived, I believe, in the time of Louis Philippe. The beautiful dancers wheeled round, their eyes brilliant with pleasure, in the arms of elegant cavaliers; one would have said that the whole of this airy troop, swaying to and fro in time to the lively flourishes of the music, was animated by one soul; everything seemed full of joy in that large and splendidly lit hall, and mothers secretly envied their daughters as they passed and repassed before them. Our oriental alone scanned with a disdainful eye this youthful enjoyment.

When it was ended,—"How is this?" said he to his conductor; "did you not tell me that I was to see here the most distinguished families of Paris?"

"Certainly," replied the other; "among those young ladies who were just now dancing before you, there were at least twenty of the grandest heiresses of France."

"Young ladies who dance! Come, come! In my country we have dancers, but they are paid for it. Our wives are never permitted to dance themselves. That is all very well for the common people!"

Remember, when needful, the contempt of this Persian prince, my dear child; and let me beg of you, work for yourself. The dance of labor is worth quite as much as that of the ball-room, when you give your heart to it. It is even worth more, very often; and next time I will tell you why.

LETTER XXV.

CARBONIC ACID.

We are going to make acquaintance to-day with a new personage, who well deserves our attention. It is the child of oxygen and carbon,* though not in the same way that you are the child of your parents.

To tell you how it is made is more than I am able. It is a *gas*, or if you like the word better, it is an *air;* for when we say "gas," we mean "air;" only it is always a different sort of air from the air of the atmosphere, which learned people are not in the habit of calling *gas*. I cannot, therefore, show you *carbonic acid* itself, for it cannot be seen any more than the air which fills an empty glass. But I can tell you where there is some, and you even probably know it by its effects, although you have never heard its name.

Do you remember, on your aunt's wedding-day, that there was a sparkling wine called champagne, at the grand breakfast? You smile, so I conclude somebody gave you a little to taste; and if so, you will remember how sharp it felt to your tongue. Do you remember, too, how the cork flew out when they were opening the bottle, and how the noise of the "pop!" startled more little girls than one? It was *carbonic acid* which sent the cork flying in that wild way; the carbonic acid which was imprisoned in the bottle, in desperately close quarters with the wine, and which accordingly flew out, like a regular goblin, the moment the iron wire which held down the cork was removed. What sparkled in the glass, making that pretty white froth which phizzed so gently, as if inviting you to drink, was the carbonic acid in the wine, making its escape in thousands of tiny bubbles. What felt so sharp to your tongue was the same carbonic acid, in its quality of acidity, for thence it has its name; the word *acid* being borrowed from a Latin word signifying the sharp pungent taste, almost *fine-pointed* as it were, peculiar to all substances which we call *acids*.

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* This is the name learned men have given to Charcoal.

It is carbonic acid also which causes the froth in beer and in new wine when bottled. It is he who makes soda-water sparkle and sting the tongue, and ginger-beer the same, if you happen to like it; and so far you have no particular reason for thinking ill of him. But beware. It is with him as with a good many others who have sparkling spirits, who make conversation effervesce with gayety, and who are very seductive in society when you have nothing else to do but to laugh over your glass. but whose society is fatal to the soul which delivers itself up to them. This charming carbonic acid is a mortal poison to any one who allows it to get into his lungs.

You remember what a violent headache your servant suffered from the other day after ironing all those clothes you had in the wash? She owed that headache entirely to this work which she did for you. She had remained too long standing over the coals over which her flat-irons were being heated. You know already that when charcoal burns, it is from the carbon uniting with the oxygen of the air; from this union proceeds that mischievous child, carbonic acid gas, in torrents, and the poor girl was ill, because she had breathed more of this than was good for her health. Observe well, that the room-door was open to let in the fresh air, and that there was a chimney, to allow the carbonic acid to escape. It was on this account that she got off with only a headache. Unhappily, there have sometimes been miserable people who, weary of life, and knowing this, but not knowing or thinking about the God who overrules every sorrow for good, have shut themselves up in a room with a brazier of burning charcoal, after taking the fatal precaution of stopping up every opening by which air could possibly get in; and when at last, in such a case, uneasy friends have forced open the well-closed door, they have found nothing within but a corpse. Then, too, there are those frightful accidents of which we hear so often, of workmen groping their way down into long disused wells who have died as they reached the bottom; or of sudden deaths in coal-pits. In general these have been owing to the poor victims encountering the long pent-up carbonic acid gas, whose poisonous breath blasted and destroyed them at once.

You may well ask why I am telling you such horrible stories, and what I am coming to with my carbonic acid? But you have more to do with it than you think, dear child. You, and I, and everybody we meet, nay, and the very animals themselves, since their machines are of the same sort as ours, are all little manufactories of carbonic acid. The thing is quite clear. Since there is a charcoal fire lit in every part of our body, there always arises from the union of the oxygen brought by the blood with the carbon it meets in our organs, that mischievous child we have been talking about; and our throat is the chimney by which he gets away. He would kill us outright were he to stop in the house.

This is how it comes about: In proportion as the blood loses its oxygen, it picks up in exchange the carbonic acid produced by combustion, so that it is quite loaded with it by the time it returns to the lungs. There it takes in a fresh supply of oxygen, and discharges at the same time its overplus of carbonic acid, which is driven out of the body by the contractions of the chest, pell-mell with the air which has just been made use of in breathing. You are aware that this air is not the same at its exit as at its entrance to the body, and that if you try and breathe it over again it will no longer be of the same use to you. That is because it has lost part of its oxygen and brings back to you the carbonic acid which it had just carried off. If you take it in a third time, it will be still worse for you; and in case you should continue to persist—the oxygen always diminishing, and the carbonic acid always increasing in quantity—the air which was at first the means of your life will at last become the cause of your death. Try, as an experiment, to shut yourself up in a small trunk, where no fresh air can get in; or even in a narrow closely-shut closet, and you will soon tell me strange news. There will be no occasion to light a charcoal fire for you in there. Enough is kept burning in your own little stove, and you will poison yourself.

You see now that the dreadful stories I was telling a short time ago have something to do with you, and that it is a good thing to be warned beforehand. And now tell me, when a hundred people—or I ought to say, a hundred manufactories of carbonic acid—are crowded together for a whole evening, sometimes for a whole night, in a space just big enough to allow them to go in and come out; tell me, I say, if that is a sort of thing which can be beneficial to the health of little girls whose blood flows so fast, and who require so much oxygen;

and whether, on the contrary, it is not one's duty to keep them away from such scenes?

There may be amusement there, I know; but the best pleasures are those for which one does not pay too dearly. I have seen the very wax lights faint and turn pale all at once, in the very midst of those murderous assemblies, as if to warn the imprudent guests that there was only just time to open the windows.

And this reminds me of a point I had nearly forgotten. Wax-candles are like ourselves. In order to burn, they must have oxygen, and, like us, they are extinguished by carbonic acid. But like us also—and indeed to a greater extent, because they consume much more charcoal at once — they manufacture carbonic acid. Hence that very illumination which affords the company so much pleasure and pride is plainly an additional cause of danger. Each of those wax-lights which is spread around with such a prodigal hand, the only fear being that there may not be enough of them, is a hungry intruder employed in devouring with all his might the scanty amount of oxygen provided for the consumption of the guests.

From each of those cheerful flames—the suns, as it were, of the festive assembly—shoots out a strong jet of carbonic acid, contributing by so much to swell out the already formidable streams of poisoned gas, exhaled to the utmost extent by the dancers. And wait—there is still something else I was forgetting. You dance. And I told you last time at what cost you have to dance. You have to make the fire burn much quicker than usual, that is, to consume a great deal more oxygen at once, and so you double and treble the activity of the carbonic acid manufacture: and this just at the moment when it would be so convenient that it should go on as slowly as possible! After this, you need not be surprised that people should look fagged and exhausted next morning. What astonishes me is that they are not obliged to lie in bed altogether, after treating their poor lungs to such an entertainment. And even if you have spared your legs, you are not much better off, as you are sure to find out in time, especially if the thing is repeated too often.

When I told you just now that the dance of labor was worth as much as the dance of the ball-room, was I right or wrong? What do you say yourself?

I could repeat the same of theatres—places of entertainment specially adapted for impoverishing the blood, and ruining the health of the happy mortals who go there, evening after evening, to purchase at the door the right of filling their lungs with carbonic acid, not to speak of other poisons. You must see clearly that such places as those are not fit for little lungs as dainty as yours; and this may help you to submit with a good grace when you see people going there without you. Grown-up people escape moreover, because the human machine possesses a strange elasticity, which enables it to accommodate itself—one scarcely knows how—to the sometimes very critical positions in which its lords and masters place it without a thought. But to do this, it is well that it should be thoroughly formed and established; for you run a risk of injuring it for ever, if you misuse it too early in life. Tell this to your dear schoolboy brother, when he wants to smoke his cigar like a man. If his lungs could speak, they would call out to him that it was very hard upon them, at their age, to be so treated, and that he ought at any rate to wait till they had passed their examinations!

But I must not get into a dispute with so important an individual, by throwing stones into a garden which is not under my care. For you, my dear child, the moral of this day's lesson—which to my mind is much more alarming than a hobgoblin tale, since it concerns the realities of every-day life—is clear ; and it is this :

Seek your amusements as far as possible in the fresh air. In the summer, when the lamp is lit, bid your mamma a sweet good-night, and go to bed. In the winter do not wait till there is a great quantity of carbonic acid in the room where the grown-up people are sitting, before you retire to your own like a reasonable girl, anxious not to do mischief to that valuable and indefatigable servant, the poor blood ! Not to mention that if she were to injure him too much, she would have to bear his grumbling for the rest of her life. We cannot change him as we change other servants.

LETTER XXVI.

ALIMENTS OF COMBUSTION.

We have spent a very long time, my dear child, over the little fire, which goes on burning secretly in every one of us, quietly devouring what little girls eat with such a good appetite, quite unsuspicious of what they are doing it for. However, if I mean to finish the history of our mouthful of bread, I must push on to its last chapter.

The *whole* of what we eat is not burnt, as you may easily suppose; for, if it were, what would the blood have left to feed the body with, and to repair in due proportion the continual destruction or waste which goes on in our organs? Our food, or "*aliments*," as the general collection of different sorts of food is called, are divided into two very distinct sets: some, which are destined to be burnt, and which are called *aliments of combustion;* others, which are destined to nourish the body, and which are called *aliments of nutrition.* I have to tell you now about these last, and you will find their history by no means uninteresting.

Learned men having detected, beyond the possibility of a doubt, the existence of these two sorts of aliments, one is tempted to think they ought to have made it known to the cooks, and that ever since so important a discovery, the dishes on all well-regulated tables should have been arranged accordingly; aliments of combustion on one side, aliments of nutrition on the other. It cannot be enough merely to give your guests a treat; you ought to provide them with everything necessary for the proper fulfilment of the claims within; and if you give some nothing but combustibles, leaving the others no share of fuel, how will they be able to manage? Nobody thinks about this, however; not even cooks, to begin with, who, as far as fire is concerned, find they have had quite enough to do with it in their cooking; and as for the guests, when they have had their dinner they go away satisfied, as a matter of course, quite as well provided for as if the mistress of the house had made her calculations, pen in hand, while writing out the bill of fare, with a view to combustion and nutrition. Now, how is that?

It is because the two sorts of aliments are, for the most part, met with together in everything we eat, so that we swallow them at once in one mouthful; and have therefore no need to trouble ourselves further on the subject. There is our bit of bread, for instance. What is bread made of? Of flour. Bread, then, must contain all that was previously in the flour. Very good. Now I will teach you how to discover in flour the aliment of combustion on the one hand, and the aliment of nutrition on the other.

Take a handful of flour, and hold it under a small stream of water; knead it lightly between your fingers. The water will be quite white as it leaves it, carrying away with it a fine powder, which you could easily collect if you were to let the water run into a vase, where the powder would soon settle to the bottom. That powder is starch—the same starch as washerwomen use for starching linen, and which our grandfathers employed in powdering their wigs. You had some put on your own hair one day when you were dressed up as a court-lady of olden time. Now, starch is an excellent combustible. People have succeeded, by means which I will not offer to detail here, in ascertaining almost exactly what it is made of, and they have found in it three of our old acquaintances, oxygen, hydrogen, and carbon, combined together in such proportions that 100 ounces of starch contain as follows :

	Ounces.
Carbon	45
Hydrogen	6
Oxygen	49
	100

I give you the calculation in round numbers, so as not to burden your memory with fractions ; and I will do the same with the other sums I shall have to go through to-day, this being, let me tell you, an arithmetical day. Besides, I could scarcely take upon myself to warrant the absolute correctness of those very precise fractions people sometimes go into. Even our learned friends squabble now and then as to which is right or wrong over the 100th part of a grain, more or less, in making out their balance, and you and I will not offer to decide between them. I always think we have accomplished wonders in getting even *near* the mark, and with their permission we will stop there.

Starch, then, of whose weight carbon constitutes nearly one-half, is of course a first-rate combustible. Indeed, one may almost consider it the parent, as it were, of at least half our aliments of combustion, for if (in consequence of a certain operation, which nature has the power of performing for herself, in certain circumstances) it loses a portion of its carbon, so that there remain but 36 ounces of it in the 100 of starch, our starch is turned into something else; now can you guess what that something is? Neither more nor less than *sugar!* Witness the grand manufactories at Colmar, in France, where bags of starch are converted into casks of syrup by a process of nature alone; so that the inhabitants of the neighborhood sweeten their coffee at breakfast with what might have been made into rolls, had it been left alone. And this is not all. Give back this starch-sugar into the hands of Nature once more by putting it into certain other conditions, and a new process begins in it. About a third of its carbon will unite itself, of its own accord, with the two-thirds of its oxygen, so as to make carbonic acid, (you are acquainted with that gentleman now) which shall fly off and away, and there will remain—what do you think?—*Alcohol*, that other combustible we talked about, and which burns even better than sugar and starch, since in a hundred ounces it contains as follows:—

	Ounces.
Carbon	53
Hydrogen	13
Oxygen	34
	100

All this astonishes you. What would you say then if I were to tell you that your pocket-handkerchief is composed of entirely the same materials as starch, and in the same proportions too, and that if a chemist were to take a fancy, by way of a joke, to make you a tumbler of sugar and water, or a small glass of brandy out of it, he could do so if he chose. Wonders are found, you see, in other places besides fairy tales; and since I have begun this subject I will go on to the end. Know then that from the log on the fire, to the back of your chair, everything made of wood, is in pretty nearly the same predicament as your pocket-handkerchief; and if people are not in the habit of making casks of syrup and kegs of brandy out of the trees they cut down in the woods, it is only, I assure you, because such sugar and brandy would cost more to make than other sorts, and would not be so good in the end. Should some one ever invent and bring to perfection an economical process for doing it thoroughly well, sugar-makers and spirit-distillers will have to be on their guard!

But we are wandering from our subject. If I have allowed myself to make this digression, however, it is because I am not sorry to accustom your mind early to the idea of those wonderful transformations which nature accomplishes, and of which I could give you many other instances.

To return to our flour. As soon as all the starch is gone out of it, there remains in your hand a whitish, elastic substance, which is also sticky or *glutinous*, so that it makes a very good glue if you choose; and hence its name of *gluten*, which is the Latin word for glue.

When dried, this *gluten* becomes brittle and semi-transparent. It keeps for an unlimited time in *alcohol*, putrefies very soon in water exposed to the air, and is easily dissolved in a wash of soda or potash. Finally 100 ounces of it contain as follows:—

	Ounces.
Carbon	63
Hydrogen	7
Oxygen	13
Nitrogen	17
	100

Observe the last material named. It is a new arrival, of which I shall soon have something to say.

But where am I leading you? you will ask, with all these uninteresting details about glue.

Wait a little and you shall hear.

You have probably never seen any one bled, which is a pity, as it happens; for if you had, you might have noticed (provided you had had the courage to look into the basin), that after a few seconds, the blood which had been taken away separated itself of its own accord into two portions; the one a yellowish transparent liquid, the other an opaque red mass floating on the top, and which is called the *coagulum* of the blood or *clot.* This *coagulum* owes its color to an infinity of minute red bodies of which we will speak more fully by and by, and which are retained as if in a net, in the meshes of a peculiar substance to which I am now going to call your attention.

That substance is whitish, elastic and sticky; and when dried becomes brittle and semi-transparent. It keeps for an unlimited time in alcohol, putrefies very soon in water exposed to the air, and is easily dissolved in a wash of soda or potash, Finally 100 ounces of it contain as follows:—

	Ounces.
Carbon,	63
Hydrogen,	7
Oxygen,	13
Nitrogen,	17
	100

This substance is called *fibrine.* It goes to form the fibres of those muscles which are contained in a half formed state in the blood.

You are laughing by this time I know, and I also know the reason why. I have told you the same story twice over. You have not forgotten my wearisome descrip tion of *gluten*, and here I am, saying exactly the same thing of *fibrine!* You conclude I am dreaming, and have made a mistake!

But no, I am wide awake, I assure you, and mean what I say. And if these details are the same in the two cases, it is for the simple reason that the two bodies are one and the same thing; *gluten* and *fibrine* being in reality but one substance, so that were the most skilful professor to see the two together dried, he would be puzzled to say which came from the flour, and which from the blood. I mentioned that our muscles existed in a half-formed state in the blood. Here is something further. The *fibres* of muscles exist previously in full perfection, in the bread we eat; and when you make little round pills of the crumbs at your side, it is composed of fibres stolen from your muscles which enable the particles to stick together; and I say *stolen from your muscles*, because they are the *gluten* which you ought to have eaten. I hope the thought of this may cure you of a foolish habit, which is sometimes far from agreeable to those who sit by you.

This, then, is the first great *aliment of nutrition*, and you may make yourself perfectly easy about the fate of those who eat bread. If little girls should now and then have to lunch on dry bread, I do not see that they are much to be pitied. There is the starch to keep up their fire, and the gluten for their nourishment, and that is all they require. The porter above is the only one who finds fault. And in these days porters have become more difficult to please than the masters themselves.

Then as to babies who drink nothing but milk, you perhaps wish to know where they get their share of fibrine.

And I am obliged to own there is none in the milk itself; but, I dare say, you know curdled milk or *rennet?* The same separation into two portions has taken place there which occurs in the blood when drawn from the arm; underneath is a yellowish transparent liquid,—that is the *whey;* above a white curd of which cheese is made, and which contains a great part of what would have made butter. By carefully clearing the curd from all its buttery particles you obtain a kind of white powder which is the essential principle of cheese, and to which the pretty name of *casein* is given because *caseus* is the Latin for cheese. I shall not trouble you now with details about *casein;* but there is one thing you ought to know. A hundred ounces of *casein* contain as follows:—

	Ounces.
Carbon, ...	63
Hydrogen, ...	7
Oxygen, ...	13
Nitrogen, ...	17
	100

Exactly like gluten and fibrine!

Now, then, you can understand that no particular credit is due to the blood for manufacturing muscles out of the cheese of the milk which a little baby sucks. He has much less trouble than the manufacturers at Colmar have in turning their starch into sugar; because in his case the new substance is not only composed of the same materials as the old one, but contains them in exactly the same proportion also.

We have a second aliment of nutrition, you see, and I must warn you that it is not found in milk only. It exists in large quantities in peas, beans, lentils, and kidney-beans, which are actually full of cheese, however strange this may seem to you. It would not surprise you so much, however, if you had been in China and had tasted those delicious little cheeses which are sold in the streets of Canton. They cannot be distinguished from our own. Only the Chinese (from whom we shall learn a great many things when we have beaten them so that they will conclude to be friends with us)—the Chinese, I say, do without milk altogether. They stew down peas into a thin pulp. They curdle this pulp just as we do milk, and in the same way they squeeze the curd well, salt it, and put it into moulds—just as we do—and out comes a cheese at last—a real cheese, composed of real *casein!* Put it into the hands of a chemist, and ask him the component parts of a hundred grains of it, and he will tell you as follows:—

	Ounces.
Carbon,	63
Hydrogen,	7, etc.

I stop there; for you surely know the list by this time!

Only the third aliment of nutrition remains to be considered, for there are but three; and I will tell you in confidence, what is stranger still, viz., that there is in reality but one! But we have had enough food for one day, and I do not wish to spoil your appetite. We will reserve the rest for another meal.

LETTER XXVII.

ALIMENTS OF NUTRITION (*continued*).

NITROGEN OR AZOTE.

There is a favorite conjuring trick, which always amuses people, though it deceives no one. The conjuror shows you an egg, holds it up to the light that you may see it is quite fresh, then breaks it; and—crack—out comes a poor little wet bird, who flies away as well as he can.

This trick is repeated in earnest by nature every day, under our very eyes, without our paying any attention to it. She brings a chicken out of the egg, which we place under the hen for twenty-two days, instead of eating it in the shell as we might have done, and we view it as a matter of course. Yet we do not say here that the bird may not have come down the conjuror's sleeve, or the hen may not have brought it from under her wing. It was really in the egg, and its own beak tapped against the shell from within and cracked it.

How has this come about? No one can have put that beak, those feathers, those feet, the whole little body, in short, into the egg while the hen was sitting upon it, that is certain. It is equally certain, then, that the liquid inside the egg must have contained materials for all those things beforehand; and if Nature could manufacture the bones, muscles, eyes, etc., of the chicken, out of that liquid while in the egg, she would probably have found no more difficulty in manufacturing your bones, muscles, eyes, etc., from it had you swallowed the egg yourself.

Here, then, is an undeniable *aliment of nutrition.* It is called *albumen*, which is the Latin word for *white of egg.* It is easily recognized by a very obvious characteristic. When exposed to a temperature varying from sixty to seventy-five degrees of heat, according to the quantity of water with which it is mixed, *albumen* hardens, and changes from a colorless transparent liquid, into that opaque white substance, which everybody who has eaten "hard-boiled eggs" is perfectly well acquainted with.

I will only add one trifling detail. 100 ounces of albumen contain as follows:

	Ounces.
Carbon, ...	63
Hydrogen, ...	—

You can fill up this number yourself, can you not? And knowing the 7 of hydrogen, you may guess what follows! After what we have talked of last time, here is already an explanation of the chicken's growth. But let us go on.

You recollect that yellowish liquid I spoke about, which lies underneath the *clot*, or *coagulum* of the blood? I will tell you its name, that we may get on more easily afterward. It is called the *serum*, a Latin word, which, for once, people have not taken the trouble of translating, and which also means *whey.* Put this *serum* on the fire, and in scarcely longer time than it takes to boil an egg hard, it will be full of an opaque white substance, which is the very *albumen* we are speaking of. Our blood, then, contains *white of egg;* it contains in fact—if you care to know it—sixty-five times more white of egg than fibrine, for in 1,000 ounces of blood, you will find 195 of *albumen*, and only three of *fibrine*; of *casein*, none.

Nevertheless we eat cheese from time to time. And we generally eat more meat than eggs, and meat is principally composed of fibrine! I should be a good deal puzzled to make you understand this, if we had not our grand list to refer to.

	Ounces.
Carbon, ...	63
Hydrogen, ...	7, etc.

Fibrine, *casein*, *albumen*, they are all the same thing in the main. It is one substance assuming different appearances, according to the occasion; like actors who play several parts in a piece, and go behind the scenes from time to time to change their dresses. The usual appearance of the aliment of nutrition in the blood is *albumen*; and in the stomach, which is the dressing-room of our actors, *fibrine* and *casein* disguise themselves ingeniously as *albumen*; trusting to *albumen* to come forward afterwards as *fibrine* or *casein*, when there is either a muscle to be formed, or milk to be produced.

Know, moreover, that *albumen* very often comes to us ready dressed, and it is not only from eggs we get it. As we have already found the *fibrine* of the muscle and the *casein* of milk in vegetables, so we shall also find there, and that without looking far, the albumen of the egg. It exists in grass, in salad, and in all the soft parts of vegetables. The juice of root-vegetables in particular contains remarkable quantities of it. Boil, for instance, the juice of a turnip, after straining it quite clear, and you will see a white, opaque substance produced, exactly like that which you would observe under similar circumstances in the *serum* of the blood; real *white of egg*, that is to say—to call it by the name you are most familiar with—with all its due proportions of carbon, hydrogen, oxygen, and nitrogen.

I wonder whether you feel as I do, dear child; for I own that I turn giddy almost when I look too long into these depths of the mysteries of nature. Here, for instance, is the substance which is found everywhere, and everywhere the same—in the grass as in the egg, in your blood as in turnip-juice! And with this one sole substance which it has pleased the great Creator to throw broadcast into everything you eat, He has fashioned all the thousand portions of your frame, diverse and delicate as they are; never once undoing it, so to speak, to re-arrange differently the elements of which it is composed. From time to time it receives some slight impulse which alters its appearance but not its nature, and that is all. As the chemist found it in the bit of salad, so he will find it again in the tip of your nose, if you will trust him with that for examination. We are proud of our personal appearance sometimes, and smile at ourselves in the looking-glass; we think the body a very precious thing; but yet when we look deeply into it we find it merely so much charcoal, water and air.

This reminds me that we have not yet made acquaintance with the new personage who was lately introduced upon the scene. *Nitrogen* or *azote*, I mean. He plays too important a part to be allowed to remain in obscurity.

You have already learnt that oxygen united with hydrogen produces water. Combined with nitrogen it produces air; but in that case there is no union of the two. They are merely neighbors, occupying between them the whole space extending from the earth's sur face to forty or fifty miles above our heads; together everywhere, but everywhere as entire strangers to each other as two Englishmen who have never been introduced! I should be a good deal puzzled to say what nitrogen does in the air: he is there as an inert body, and leaves all the business to the oxygen. When we breathe, for instance, the nitrogen enters our lungs together with its inseparable companion, but it goes out as it went in without leaving a trace of its passage. Nevertheless, as sometimes happens among men, the one who does nothing takes up the most room. Nitrogen alone occupies four-fifths of the atmosphere, where it is of no other use than to moderate the ardent activity of king oxygen, who would consume everything were he alone. I can compare it to nothing better than to the water you mix with wine, which would be too fiery for your inside if you drank it by itself. This is what nitrogen does. It puts the drag on the car of combustion; as in society, the large proportion of quiet people put the drag on the car of progress (let us for once indulge ourselves in talking like the newspapers!); and such people are of definite use, however irritating their interference may appear in some cases. The world would go on too rapidly if there were nothing but oxygen among men. We have quite enough in having a fifth of it!

But what in the world am I talking about? Let us get back to nitrogen as fast as we can!

We must not imagine there is no energy in this quiet moderator of oxygen. Like those calm people who become terrible when once roused, our nitrogen becomes extremely violent in his actions when he is excited by another substance, and is bent on forming alliances. Sometimes the usually cold neighbor unites itself to oxygen in the closest bonds; in which case the two together form that powerful liquid, *aqua-fortis*, of which you may have heard, and which corrodes copper, burns the skin, and devours indiscriminately almost everything it comes in contact with. Combined with hydrogen, nitrogen forms *ammonia*, which is still often called by its old name *volatile alkali;* one of the most powerful bodies in existence, and one for which you would very soon learn to entertain a proper respect, if somebody were to uncork a bottle of it under your nose. Finally, nitrogen and carbon combined, produce a quite foreign substance (*cyanogen*), resembling neither father nor mother in its actions and powers, to the confusion of all preconceived ideas, when Gay-Lussac, a Frenchman, introduced it to the world, where it fell like a bombshell upon the theory of chemical combinations. This impertinent fellow, combining with hydrogen in his turn, produces *prussic acid*, the most frightful of poisons; one drop of which placed on the tongue of a horse strikes it dead as if by lightning.

You perceive that you must not trust our worthy friend too far. You have learnt, however, elsewhere, that it is not equally formidable in all its combinations. Those very substances which, when paired off into small separate groups, destroy all before them, constitute, all four together, that precious aliment of nutrition of which we are formed. Moreover, its real name is "*azotized aliment*," because it is the presence of nitrogen or azote in it, which, above all, determines its quality, so that people are in the habit of estimating the nourishing power of our food by the amount of nitrogen it contains. In fact, nitrogen seems to be a substance especially inclined towards everything that has life. His three comrades wander in mighty streams, so to speak, through every part of creation; but he, excep in the vast domain of the atmosphere, where he reigns in such majestic repose, is rarely met with, except in animals, or in such portions of plants as are destined for the support of animal life.

On this point I will tell you the history of his original name, *azote*, which you will find curious enough. A short time before the French Revolution, in 1789, the principal properties of this gas were made known to the world by a learned Frenchman, who may be almost considered the father of modern chemistry, and whose name I must beg you to recollect.* He was called *Lavoisier*. While endeavoring to account satisfactorily for *combustion*, which before his time people explained any way they could, Lavoisier succeeded in separating our two friends, the neighbors in the atmosphere, one from the other, and was the first man in the world who managed to secure in two bottles—on the one hand, the bubbling oxygen freed from his tiresome mentor ; on the other, the sober azote, snatched away from his giddy pupil. What he did with the bottle of oxygen matters but little to us ; but in the bottle of *azote* he plunged, by way of experiment, an unfortunate mouse, and subsequently a little bird, both of whom, finding no oxygen to breathe, died one after the other. Nothing could live in it, as you may suppose ; and Lavoisier thought it must be right to give so destructive a gas the name of *azote*, which in Greek means "*opposed to life.*" Meantime, science went on progressing by the gleam of the lamp he had lit, and then followed the discoveries of his successors, who forced their way into the obscure laboratory where the elements of living bodies are prepared. And at last it was ascer-

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*Dr. Daniel Rutherford (Edinburgh) discovered the existence of *Nitrogen*, A. D. 1772 ; but he never investigated its character.

tained that this *azote*, opposed to life as it was thought to be, was actually an essential property of life; that it accompanied it everywhere, and that without it the whole framework of the animal machine would fall to pieces. It is still known by its old name, which custom had sanctioned; but I imagine no learned man can ever utter it now without a feeling of humility, and without the thought that the future has possibly many contradictions in store for him also. Besides, nitrogen has to pass through many fine-drawing processes before it attains that post of honor which has been assigned to it in the animal kingdom. The animal himself can do nothing with it, unless it has been previously absorbed and digested by the vegetable, and the vegetable in its turn could get no good from it, were it to remain isolated and indifferent in the bosom of the atmosphere. It is only when it has formed one of those combinations I have been telling you about, and more particularly the second, which produces *ammonia*, that it fairly enters upon the round of life. And then, in the mysterious depths of vegetable existence is organized that wonderful *quadrille* of the *aliments of nutrition*, the history of which has now been sufficiently explained to you.

The vegetable kingdom, therefore, is simply the great kitchen in which the dinner of the animal kingdom is being constantly made ready; and when we eat beef, it is, in fact, the grass which the ox has eaten, which nourishes us. The animal is only a medium which transmits intact to us the *albumen* extracted in his own stomach from the juices furnished to him in the fields. He is the waiter of the eating-house; the dishes which he brings us have been given him already cooked in the kitchen. But to appreciate properly the service he renders us we must remember that the dishes to be obtained from grass are very, very small, and that it would be a great fatigue to the stomach if it could only get at such tiny scraps at a time; as, alas! has sometimes happened to the famine-stricken poor, who have tried in vain to support life from the grass in the field. But these minute dishes are brought to us in the mass whenever we eat beef, and our stomachs benefit accordingly. Do not forget this, my child; and when mamma asks you to eat meat, obey her with a good grace; if, that is to say, you wish to grow up to be a woman.

LETTER XXVIII.

COMPOSITION OF THE BLOOD.

One word more before we finish. We must not leave off without bidding a last farewell to the good servant of whom we have spoken so much; the model steward so exact in giving back everything he receives—the factotum of the house in short. We have watched him at work long enough, but I have not yet described him personally to you, nor told you exactly what he is composed of.

And here I shall be obliged to begin again with figures and calculations, although I am told young people are not very fond of them. Nevertheless, none of us can manage our affairs properly without them. Hereafter, when you are at the head of a family, you will be obliged to practise arithmetic, if you want to know what is going on in your house. Never allow yourself to look upon what is necessary as wearisome; the true secret of being punctual in our duties is to throw our heart and interest into them.

I choose, therefore, to suppose that you will be interested to know that 1000 ounces of blood generally contain, (for there are shades of difference between one sort of blood and another) 870 ounces of the *serum* I have been talking about, and 130 ounces of *clot*. At first sight one would take the quantity of *clot* to be much greater than it really is; but in the state you see it, in the basin, it contains a considerable amount of water, which belongs by right to its companion *serum*, and which has to be drained away from it before it can be weighed.

Now, in our 870 ounces of serum, we shall find, to begin with, 790 of water; do not be astonished at the quantity. Most of the weight of all animals is produced by water; they weigh comparatively nothing after being thoroughly dried in a stove—when they are dead of course—for neither animal nor plant can live unless saturated with water. This, by the way, may serve to explain the ease with which we can keep ourselves floating in water; we are not much more than water ourselves! Were it not for those abominable bones which are a little bit heavier than the rest, we should never sink unless a stone were hung round our necks.

I repeat then; 790 ounces of water in 870 of *serum*, which leaves 80. Of this, *albumen* furnishes seventy, and the ten others, with the exception of a small portion of fat which floats here and there ready-made, are *salts*. It would take too long to explain what *salts* are here, but there is one sort of salt you know perfectly well; viz., that which is put on the dinner-table in a salt-cellar. And it is the most important of all. More than half the ten ounces of salts consist of it alone, which will make you understand better than before, what I explained with reference to the stomach; that is, why we put salt in our food. The porter above is quite up to his business when he asks everyone who enters to produce his little bit of salt. It is an attention which the blood appreciates very highly, although table-salt is of no great use to him in his building operations; but it evidently keeps him in good humor, and he would work badly without it. It is the same with all the animals man makes use of, and even the plants he cultivates, find that salt gives them an appetite. And it would almost seem as if nature had purposely dealt with us in this matter on a magnificent scale. She has made salt-magazines of the sea and the bosom of the earth, where it exists in prodigious masses which cost nothing but the labor of stooping to pick up, except in countries where a gentleman called a tax-gatherer, stands by to count the lumps and allow them to pass on by paying a duty. For my part, if I were the government—this is a secret between you and me, mind—I would look out for something else to stand in the place of the salt-tax. It is not well to interpose between man and the gratuities of Dame Nature, and to make him pay more heavily for the blood's chosen friend than she meant him to be charged.

But to proceed, the kitchen-salt being deducted from the ten ounces of salts-in-general, there remain altogether from four to five ounces, which contain——. But here I stop, for it puzzles me very much how to go on! Enough, that to enable you to follow me, you would require at least as much knowledge of chemistry as will be expected of a young man who has to pass an examination in medicine. Fancy the contents of a whole druggist's shop! I will tell you a few names, that you may have a specimen of the style in use, but I forewarn you that they are not inviting: *hydrochlorate of ammonia; hydrochlorate of potash; carbonate of lime; sulphate of potash; phosphate of lime; phosphate of magnesia; lactate of soda.* I spare you the others, for many others there are, without counting those which have not yet been discovered! All these things are to be found, I must tell you, in fibrine and albumen, but in such minute quantities that it is scarcely possible to recognize them

In the serum, for instance, the gentlemen are so very small, and so completely entangled one with the other, that it is startling to think of the skill and patience requisite for making them all out, to say nothing of affixing the right name—uncouth as it may seem—to each grain of this almost imperceptible dust! He who first called man an epitome of creation, scarcely knew how truly he was speaking, for man bears about in his veins, ascertained samples of at least half the primitive substances from which all others are made, and if the whole of them should some day be found to be there, I for one should not be surprised.

This is well worth knowing, is it not? and I have not come to the end of my story yet.

We have still the 130 ounces of *clot* to speak about. But their contents are easily reckoned. Three ounces of fibrine and 127 of *globules*.

Here, however, we enter upon such a world of wonders, that I am quite delighted to be able to finish with it. It will be the masterpiece of our exhibition!

You feel quite sure blood is red, do you not? Well! it is no more red than the water of a stream would be, if you were to fill it with little red fishes. Suppose the fishes to be very very small, as small as a grain of sand; and closely crowded together through the whole depth of the stream: the water would look quite red, would it not? And this is the way in which blood looks red: only observe one thing; a grain of sand is a mountain in comparison with the little red fishes in the blood. If I were to tell you they measured about the 3,200th part of an inch in diameter, you would not be much the wiser, so I prefer saying (by way of giving you a more striking idea of their minuteness) that there would be about a million in such a drop of blood as would hang on the point of a needle. I say so on the authority of a scientific Frenchman—M. Bouillet. Not that he ever counted them, as you may suppose, any more than I have done; but this is as near an approach as can be made by calculation to the size of those fabulous blood-fishes, which are the 3,200th part of an inch in diameter.

These littles fishes are called *globules;* but they are not exactly shaped like *little globes*, as the word would lead you to suppose. They are more like little plates slightly hollowed out on both sides. The central nucleus is surrounded by a flattened margin rather bladdery in appearance, of a beautiful red color, formed of a sort of very soft and very elastic jelly. I scarcely need tell you that all this was discovered through the microscope, and moreover, by examining the blood of frogs, in which the globules are much larger than in ours.*

It was in 1661—rather more than two hundred years ago—that an Italian and a Dutchman discovered, each by himself in his own country, the microscopic population of the blood. The name of the Italian is not very difficult—*Malpighi.* As to the Dutchman's, you must pronounce it in the best way you can—he was called *Leeuwenhoek.* You smile, but he was nevertheless one of the first men who really comprehended what a wonderful auxiliary human science had just got hold of in the microscope, and he has helped to open the eyes of the world to the marvels of miniature creation. So co tent yourself, young lady, with mis-pronouncing his name, and beware of laughing at it! Names are something like faces, one may live to be ashamed of ridiculing the wrong one.

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* Authentic portraits of these globules drawn—so to speak—by Nature herself, are to be seen on the admirable Photographs obtained by Bertsch, with the aid of the solar microscope, invented by himself and Arnaud. There you see them magnified 250,000 times, and may study them at your ease, and verify my description for yourself without any fear of being deceived. You must persuade your father to procure one. This result of photography is among the wonders of modern science.

This discovery of the globules of the blood was destined to throw great light upon the way in which the *nutrition of the organs* was carried on. Modern chemists, who are always fond of investigation, have examined what they are made of, and can find little else in them but *albumen.* Out of our 127 ounces of globules, 125 are albumen ; and these, with the 70 ounces which we found before in the serum, make up the 195 ounces (of albumen) which I told you were contained in the 1,000 ounces of blood. Forgive me all these ounces and figures. Exact accounts give exact information.

These globules, then, are composed almost entirely of albumen. Nearly two-thirds of all the albumen in the blood is concentrated in them ; and you know now the use of albumen, viz., that it is the foundation of all the buildings of which the blood is the architect. Everything leads us to believe that the formation of globules in the blood is the last touch given by nature to that magical provision begun in the vegetable, continued in the stomach, and finished in the veins, to which, in combination with carbon, hydrogen, oxygen, and nitrogen. we are indebted for the subsistence of every portion of our body. Thus the blood-globules may be considered as albumen which has finished its education, and is ready to go into the world ; while the albumen of the serum is, like our young friends, the generations in reserve, who are still at school awaiting their turn.

This is more than a mere supposition. Scientific men have taken to themselves, on their own authority, all sorts of rights over animals, and we profit basely enough by their crimes—I will not withdraw the word—in order to increase our knowledge. Accordingly, they conceived the idea of opening the veins of animals, and allowing the blood to flow until the victim was prostrate and motionless as a corpse. This done, they proceeded to fill the exhausted veins with blood, similar to that which had been withdrawn, and with the blood, life was seen gradually to return, till the animal rose from the ground, walked, and resumed its disturbed existence, as if nothing had happened. The interesting part of the experiment to us is, that if serum only, without globules, be restored to the unfortunate animal, it is of no use whatever, and the corpse does not revive.

It is evident, then, that all the power and virtue of the blood lies in the globules ; and according as their number is great or small it is "rich" or "poor," as it is called ; and where their number is not up to the mark, the blood acts more feebly on the organs, life is calmer, and people are no longer troubled with emotions—in other words, with violent heats of the blood. Hence the impassible character of *lymphatic* people, who often get on in the struggle of life better than others, because they are never in a hurry, and know how to wait for opportunities. You will occasionally hear the word *lymphatic*, for it has become the fashion, and it is time for me to explain it ; but unluckily the explanation is not in its favor.

You remember those little scavengers we spoke about formerly, who came from the depths of all the organs, carrying away with them the worn-out building materials, and covering the surface of the body with an inextricable net work of tiny canals. These canals are called *lymphatic vessels*, in consequence of being filled with a liquid which is called *lymph* (*water*, in

Latin), but why I cannot tell you, for it is, in fact, simple *serum*. There was a very simple way of ascertainig this by making out an inventory of the contents of the *lymph* liquid, and when this was done, they were found to consist of water, albumen, and the salts of serum ; there was even a little fibrine ; the only thing wanting was *globules*.

How the truant serum finds its way into the lymphatic vessels is probably as follows :—I have already mentioned the inconceivable delicacy of the capillary vessels, those last ramifications of our arteries and veins. It needs all the impulsive power of the heart to enable the blood to force its way through these narrow passages ; and minute as are the globules, it would seem that they have but just room to pass, for in examining under the microscope a corner of the tongue of a live frog, the globules have been seen doubling themselves up to pass through the capillaries, resuming their natural form afterwards.

It was this, indeed, which made me tell you just now that their margins were elastic. During this momentary crush, part of the serum being forced on too fast, oozes through the wall of the over-filled capillaries, as water oozes through the leathern pipes of a fire-engine, and hence probably the appearance of serum or *lymph* in the organs, where it is immediately sucked up (i. e., *absorbed*) by the lymphatic vessels. Now, you will easily understand that the larger the proportion of serum in the blood, the greater will be the quantity to be expelled in passing through the capillaries, and the more will the lymphatic vessels swell. In such cases the temperament or constitution is said to be *lymphatic*. If, on the contrary, the globules are in excess, the lymphatic vessels receive less serum, and diminish in size. The temperament is then called *sanguine*, as if there were no serum in the blood. You shall be judge yourself, knowing what you now do, whether it would not be more reasonable to call such temperaments *serous* and *globulous*. At any rate those names would give people an idea of the real state of things, and teach them that there were such things as globules in the blood.*

To conclude, I must give you an account of the two ounces which still remain of the 127 of globules, albumen taking up only 125, as you know. Those two poor little ounces—the remainder of the thousand with which we started—would you believe it?—they alone have the honor of conferring upon the blood its beautiful red color. They constitute the coloring matter of the globules, and you will never guess its chief element. It is iron; ay, actually iron, young lady—the iron of swords and bayonets. We often accuse it of tinging the earth with blood; and you may now know further, that it reddens blood itself by way of compensation. Do not trouble yourself as to where it comes from. Our fields are full of it, our very plants have stores of it. It sometimes happens that our digestive apparatus, put out of order by other occupations, fails to make use of the amount of iron offered to it; in which case the blood is discolored, and the face turns pallid as wax: this is an illness requiring great care. If it should ever befall

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* Here is a summary of the contents of 1000 oz. of blood:—

				Ounces.	
Serum.	Water			790	870
	Albumen			70	
	Salts			10	
Clot.	Fibrine			3	130
	Globules	Albumen	125	127	
		Coloring matter	2		
					1000

you, you will not be surprised, after to-day's lesson, to hear the doctor say that you must have some iron. But be easy—you will not have to swallow it whole If you will take my advice, you will obey the doctor's orders as soon as you can.

Not that looking pale signifies any thing: indeed, some young ladies think it an advantage. But it is no advantage to any body when the blood-globules are distressed for want of their proper supply of iron, and do their work grudgingly, like ill-fed laborers. Nothing can go on without them, you know, and they are people whom it is not well to leave too long out of sorts. Else languor comes on; languor which is the beginning of death: and pray remember that iron, which so often causes death, is equally useful for keeping it at bay. By sending it to the discolored globules, you give them back their energy and brilliancy together.

I have come here to the end of all that is known with any certainty about these wonderful globules which are to us the medium of life. Shall I go further, is the question, and take you with me into the fields of supposition, so full of noxious weeds? And yet why not? Science owes its present position to the praiseworthy rule of never adopting any theory which is not supported by well-established facts; and I would be the last to advise a change. Were I to tell you, what I am now going to say to you, at a meeting of the British Association of Science, they would turn me out of the room, and with very good reason. Nothing ought to be taught there but what can be proved. But this is of no consequence to you and me, and we have a right to amuse ourselves a little, after having worked so hard.

Well, there is an idea which nothing shall ever drive out of my head, however imperfectly it may be proved as yet; namely, that each of our globules is an animated being; and that our life is the mysterious result of these millions of lesser lives, each of them insignificant in itself; in the same way that the mighty existence of a nation, is a compound of crowds of existences, each, for the most part, without individual importance. Take our own or any other country as an instance; where millions of brains, many of them by no means first-rate in power, go to form a national character, the highest (as each *nation* is apt to think of itself) in the world. According to this idea, you must be a sort of nation yourself, my dear child, which is gratifying to think of on the whole.

This is much more extraordinary than what I told you some time ago, of the individual life of the organs, each of which on this new system would be a province in itself! Do not exclaim too hastily. Whether the globules are animated or not, it is very certain, let me tell you, that your life depends entirely upon them; that it is weakened if they are weakened; that it revives with them; and that whether you attribute individual life to them or not, makes no alteration in the fact: their action upon you remains the same. And he must be a very clever man who can show me the exact difference between action and life. Hereafter, when we have descended the scale of the animal world together, and are arrived at the study of what are called microscopic animals, you will better understand the words which appear so strange to you now. What little our feeble instruments have revealed to us so far, of the history of those globules, places them almost on a level with those strange creatures, inexplicable to us, which are found in innumerable multitudes, in a variety of liquids. We trace in them the beginning of organization; their form and size are alike in all individuals of the same species; and species vary enough to induce one to believe, that there is a necessary relation between an animal's way of life and that of its globules. If the microscope has not yet caught them in any overt living act, who can be surprised? it is only dead blood which has been submitted to the test. They ought to be observed in the exercise of their functions, in the living animal itself, as has been done to some extent in the frog; and if our foolish chat could influence scientific observers, I would say to them what M. Leverrier said years ago to the astonished astronomers: "Look yonder; you ought to see a light there with which you are not yet acquainted!"

I am carrying you a long way on the wings of my fancy, my dear child; but have no fears; I will not let you fall. This life of our globules, which would, after all, be only one mystery the more among many, opens before our eyes a magnificent vista of the uniformity in the scheme of creation; which goes on repeating itself, while enlarging its circles to infinity. We may, all of us, be only so many globules of the great invisible fabric of humanity, in which we go up and down one after another; and those vast globes which our telescopes follow through celestial space, may be but globules of one, as yet unknown, to which the Almighty alone can give a name.

Take this page to your father, my dear child, if you do not understand it rightly; and now, shake hands, my history is ended!

PART SECOND—ANIMALS.

LETTER XXIX.

CLASSIFICATION OF ANIMALS.

'It is dangerous to show man how much he resembles the beasts, without at the same time pointing out to him his own greatness. It is also dangerous to show him his greatness, without pointing out his baseness. It is more dangerous still to leave him in ignorance of both. But it is greatly for his advantage to have both set before him.'—*Pensées de Pascal.*

The man who wrote that, my dear child, did not trouble himself much about children. He was one of the gravest specimens of literary genius—a man who can scarcely be said to have ever been a child himself; for as the story goes, he was found one day, when only twelve years old, inventing geometry, and his father only saved him from trouble, by putting the great book of Euclid into his hands; and, at sixteen, he wrote a treatise on *Conic Sections*, which was the wonder of all the learned men of the day. I have not a very clear idea of what Conic Sections are myself; but I tell you this to show that Pascal was a very profound and learned man, under whose authority, therefore, I am very glad to take shelter, now that I am going to set before you the very startling points of resemblance which exist between you and the beasts.

As to your greatness, it delights me to explain it to you. It is not due to the handsome clothes you wear when you are going out, nor to the luxurious furniture of mamma's drawing-room, but to the possession of that young soul which is beginning to dawn within you, as the sun rises in the morning sky, and pierces through the early mists ; in that growing intelligence which has enabled you to understand so far all the pretty stories I have told you ; in that fresh unsullied conscience, which congratulates you when you have been good, and reproves you when you have done wrong: all of them gifts which are not bestowed on the lower animals, or certainly not to the same extent as upon you—gifts by which you rise more and more above them, the more they are developed in yourself. Your baseness—but, begging Pascal's pardon, I cannot call it baseness—your connecting link with the brute creation lies in those other gifts of God which you and they share in common—in those wonders of your organization, which we shall now meet with in them again, in full perfection at first, and that in every respect ; by which fact you may learn, if you never thought of it before, that the lower animals come from the same creating hand as yourself, and ought to be looked upon to some extent as younger brothers, however distasteful such a notion may seem at first.

Societies have been established of late, both in France and England, for the protection of animals ; and a noble and honorable task they have undertaken, in spite of the jokes that have been made at their expense. It is a mischievous cavil to tell people who are doing good in one direction, that more might have been done somewhere else. Everything hangs together in the progress of public morality, and you cannot strike a blow at cruelty to animals without at the same time making a hit at cruelty to man. And the best argument in favor of the rights of beasts to protection, will be found in the tour you and I are now going to make together through the different classes of the animal creation.

Let us begin with the horse—one of the beasts which oftenest needs our protection. Give him the mouthful of bread whose history we have just finished. He accepts it as a treat, and needs no pressing to eat it. And if it could tell you all its adventures afterwards, you would find that you were listening to precisely the same story as your own over again; that nothing was different, nothing wanting. First of all—teeth to grind it, and a tongue to swallow it with, as a matter of course. Next a *larynx*, which hides itself to avoid it, and an *œsophagus*, which receives it, just as in your case; a stomach with its *gastric juices*, the same as yours, in bagpipe form, and its *pylorus*, like your own; a *lesser intestine*, into which bile pours from a liver like yours; *chyliferous vessels* which suck up a milky chyle, as with you; farther on a *large intestine;* and so on to the end. Nor is this all:—the horse has also a heart, with its two *ventricles*, and its double play of valves; a heart which the little girl in our tale might confidently have exhibited to the engineers as her own, but that it would have been somewhat too big, of course; into which heart, as into ours, comes *venous* blood, to be changed afterwards to *arterial;* in lungs to which the air keeps rushing, forced thither by the see-saw action of a *diaphragm*, as faithful a servant to him as to you. And those lungs like our own, are a charcoal market: the same exchange takes place there, of carbonic acid for oxygen, as in ours, an unanswerable proof that the stove inside the horse burns fuel in the same way as our own: and if you were to place the thermometer inside his mouth (for we are polite enough to call it his mouth), it would mark 37 1-2 degrees of heat (centigrade)—a difference from ourselves not worth mentioning. Finally, if you examine his blood, you will meet with the same *serum* and *clot*, the whole company of *hydroclorates*, *phosphates*, *carbonates*, *&c.*, from which we shrank before, and globules made like your own; having the same construction, and the same life, or action, if you like it better. I need scarcely add that 100 oz. of its *fibrine* and *albumen* contain

Of carbon - - - -	63 oz.
Of hydrogen - - - -	7

This is understood all along as being the case everywhere, from man down to the turnip; so that, like you, this noble animal, as the horse is called, is in point of fact only so much carbon, so much water, and so much air, joined to a handful of salt, which represents the earth's share in the bodies of animals.

You must confess that, if we cannot quite call the horse a fellow-creature, he is nevertheless very like us. And it is the same with all those animals which man makes use of as his servants, and which have really a sort of right to the protection of society, since they form, to a certain extent, a portion of the human family. I do not speak here of the dog, who pays his taxes, poor fellow, in his quality of friend to man.

When I think of the almost identical organization of man and his next-door neighbors, I am astonished how it could possibly have come into the head of a certain learned individual (I will not mention his name), when drawing up a plan of natural history, to give to man a separate kingdom, as a sequel to the three kingdoms already established—the mineral, vegetable, and animal. One might have forgiven Pascal if such an idea had got into his head after writing his treatise on Conic Sections; there being nothing in them to throw light on such a subject. But in a naturalist, an observer who had spent his life in the study of living creatures, the thing seems almost incredible. Possibly he had reasons for what he did, but he certainly did not find them in the subjects of his studies.

Forgive me, my dear child, for forgetting you in this fit of indignation upon a point you cannot care much about. It leads me naturally enough to my present business, which is none of the easiest, but you must help me by paying attention. I am going to describe the *classification of the animal kingdom.*

There are a terrible number of animals, as you know ; and if we wish to study them to any real purpose, we must begin by introducing some sort of order into the innumerable crowds which throng, pell-mell, around us for observation. We should otherwise never know where to begin, or when we had come to an end.

There are many ways of setting a crowd in order, but they all go upon the same plan. The individuals composing the crowd are parcelled off into companies, each company having a distinguishing mark peculiar to those who compose it. Thus the first division is into a few large companies, which are afterwards subdivided into smaller ones, and those into others still less, until the divisions have gone far enough. And this is what is called a *classification.*

Let us imagine, as an example, a large crowd in a public garden ; I will soon classify it for you. I shall put the men on one side and the women on the other. Then—to begin with the women—I shall subdivide them into married and single. Then among married women I shall make a company of mammas, and another of those who have no children. Among the unmarried I shall have a group of those who have never been married—

girls, that is—and another of widows—those who were once married, but are so no longer. Then, following the girls, I shall separate them into tall and short. And among the short ones I shall divide the brunettes from the blondes, and so I shall get at last to a little blonde girl, whose classification (were she a soldier) in military rank would be as follows:—*squadron* of blondes; *company* of shorts; *battalion* of girls; *regiment* of unmarried women; *division* of women. The division of men could be carried out in the same manner; and thus we should classify our mob into complete military order. This is easy enough, however; but the classifying of animals is a very different affair, and I will tell you why. We ourselves require a classification to study them by, though none was needed for their creation. The Almighty has formed them all on one uniform plan, around which He has, if I may so express it, lavished an infinity of modifications separating species from species, yet without placing between the different species those fixed barriers which we should require now to enable us to classify them strictly. You who are learning the pianoforte have perhaps been told the meaning of a *theme* of music—the first idea of the composer who follows it throughout the piece from one end to the other, embroidering on it, as on a bit of canvas, a thousand variations melting one into another. Such is pretty nearly, if we may venture the comparison, the way in which we can picture to ourselves the Almighty moving through the work of animal creation. Step in afterwards and divide away into regiments and battalions, if you please. Nature permits it, but she will never, to accommodate your classifications, separate what in her is really united.

There is still a way, however, and that is to do as I did just now in the case of the crowd. To take viz., only one *character* (as we call a distinguishing mark in natural history), and to throw together all the individuals which possess it, the blondes, the shorts, the girls, &c. In this way it may soon be done; but what is the result? You are in one class, your eldest sister is in another, your mamma in a third, and your brother in a different division altogether, a long way from you all. Such a classification is called *artificial*, and you can see at once that it is worthless.

The most natural plan is to put together those that are of the same family; and the classifications made on this principle are called *natural* classifications.

It is a classification of this sort which has been adopted for the animal kingdom. People have taken all the animals which possess in common not one character only, but a collection of characters of the most important kind, *dominant characters*, as they are called; and of these animals they have formed, to begin with, large primary groups; subdividing these afterwards according to the secondary differences, which distinguish different species in the same group from each other.

In this manner all the different sorts of animals are included in different systematic divisions of one vast whole, through which it is easy to find one's way, because there is a beginning and an end; and in which animals of the same family are always grouped side by side. Were I to mention all the divisions of this immense classification at once, you would find the account a little long, and not very amusing. We will go through them by degrees therefore, and, to simplify matters, will, throughout the whole, only consider those particular characters which are connected with our special study, the nourishment of life, that is to say: so that you will always find yourself on well-known ground.

I must tell you once for all, however, that it is with this as it is with grammar. Here and there are—and it cannot be avoided—certain exceptional cases which keep protesting timidly against the arbitrariness of rules; but no matter; we must be contented with what we can get, and be grateful into the bargain to those who have given us this skillful classification, at once so ingenious and useful, in spite of its inevitable imperfections. What is impossible is expected of nobody. You could not understand, even if I wished to explain it to you, the amount of science, labor and genius requisite for making out that long list, which, tiresome as it may seem to children, is absolutely beautiful in the eyes of learned men; too beautiful, perhaps, and I will tell you why when we have finished. Meantime, as the best reward we can give to those who have done us some great service is to teach their names to children, I will tell you, before bidding you good-bye, to whom we owe this classification, the details of which I do not enter upon to-day.

In the first place, we owe the method employed in its establishment, the method of *natural classification*, *i.e.*, to a learned man of the last century—a learned Frenchman, Bernard de Jussieu—who tried it upon plants; another large flock by no means very easy to put in order, as you may convince yourself any day by studying botany. The man who applied this system to animals was also a learned Frenchman, the clearness of the French mind adapting them peculiarly for that sort of work. And he, too, is one of the glories of that nation. His labors and discoveries gave a perfectly new impulse to the study of nature. It was George Cuvier, whose statue you may see at Montbéliard, if you should ever go there. Not that Cuvier carried through this gigantic work alone, though the credit of it is justly his due, he having directed and inspired it. He was assisted by many. But among his assistants there was one, Laurillard, the most modest, yet the most active of all, whose name I will mention also, because, like the others, more or less celebrated, he has never had his reward.*

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* In the earlier editions of this work, there was, in this place, a severe reproach upon Cuvier for not having given proper credit to Laurillard. This reproach I have since learned was unjust. M. Valenciennes himself, one of the most illustrious of the collaborators of the great Cuvier, has written me a letter in which he defends the reputation of his friend with a warm indignation which does honor to both of them; and cites passages in which Cuvier has spoken of Laurillard, and among others, in the third volume of the *Ossements Fossiles*, p. 32, ed. of 1822.

It only remains for me, therefore, to let the lash, which I was laying upon the shoulders of another, fall now upon my own, and to deplore the too great facility with which I had credited, without sufficient proofs, an assertion which I had otherwise good reason to believe to be exact—coming to me, as it did, from Montbéliard himself, on the testimony, it is said, of the family of Laurillard. From this avowal, a little painful, I confess, my young readers may learn the inconvenience of rashly condemning others! As I said in the concluding passage, which truth, only too late, now compels me to suppress—“The truth is sure to come out at last.”

LETTER XXX.

MAMMALIA. (*Mammals.*)

Do you remember of my talking of the *vertebral column* when I was describing that great artery, the *aorta*, to which it forms a rampart of defence? I should not have named it without explanation, but that you had only to pass your hand down your back to find out what it was. Now the *vertebral column*, or backbone, is one of those *dominant characters* which always carries along with it a train of other points of resemblance in the animals where it is found. It has been chosen, therefore, as the rallying-point of the first great group. I must tell you beforehand that there are four of these groups, four large companies, *i.e.*, which naturalists have called by various names; as Groups, Sections, Primary Divisions and even Branches; in this case comparing them to four great branches of a tree, going off in different directions from the same trunk.

And, first of all, we have to begin with the group of the *Vertebrata*—vertebrata animals—vertebrata being a word which explains itself.

Of course we ourselves belong to this group. In fact, we are at the head of it; but it descends far below us. It goes on to the frog and the fish, and includes the monkey, the ox, the fowl and the lizard; for all these creatures possess the vertebral column. The frog does not appear to be very much like us at first sight; and yet, by virtue of its vertebra, it has its points of resemblance to us, which are worth the trouble of considering. Vertebrated animals are all furnished with a head, containing a brain, which gives its orders to the whole body ; they have all an internal skeleton, that is to say, a system of bones linked together, forming a solid base by which all the organs are supported. I was going to add that they have all four limbs ; but here the serpent glides in to call me to order, and to hiss at our childish craving for fine-drawn divisions, in perfect order, where there is an exactly proper place for everything. However, each has, without exception, a heart, with its network of blood-vessels ; red blood, under its two conditions of arterial and venous ; and also a digestive tube, acting, on the whole, pretty much like our own. I do not insist, mind, upon this last point, viz., that of the digestive tube ; for we shall see, by-and-by, that it is a character beyond the pale of the primary groups. It is the fundamental character of the trunk itself, which necessarily exists, therefore, in all the groups ; and, as I told you in my first letter, you will find it everywhere.

This is—to let you into the secret at once—the theme on which the Great Composer has based all His infinite varieties of animal life ; and herein lies the uniformity of the animal creation, that startling uniformity which has given so much offence to many learned men, and which is so obvious that it will strike you of itself, I feel sure. But I reserve this subject to the end of my letters, when you will have heard all, and be able to judge for yourself.

It would be plunging back into confusion to attempt to examine all the vertebrated classes at once. After making a division you must go on. The groups have, therefore, been subdivided into *five classes*, which we will study in succession, only naming each now: viz. *mammals*, *birds*, *reptiles*, *fish*, and *batrachians*. Do not alarm yourself at this last name: it is a Greek word, meaning simply frogs.

The mammals are our immediate neighbors. Mammalia are the animals which produce milk. They bring forth their young alive, and give suck to them as soon as they are born. This was your first nourishment, my dear child, so you yourself are a little mammal.

What I said to you in the last letter about the horse, applies pretty nearly as well to all mammals. We shall not, therefore, have any great variations to notice here. Nevertheless, as these are the animals which interest us most nearly, as they are in fact our nearest of kin, so to speak, and those with whom we have the most to do, we will now pass in review the different orders of which their class is composed. I must explain to you that the *classes* are subdivided into *orders*, the orders into *families*, the families into *genera*, the genera into *species*; as in armies divisions subdivide into regiments, regiments into battalions, &c. It became necessary, moreover, to make use of special names, in order to make these subdivisions comprehensible, and the following are those which have been adopted.

ORDER 1. *Bimana* (*two-handed*).

Here we may pass on at once, for we have discussed this order enough already. We are *bimane* ourselves, since we have the distinction of possessing two hands. Yes; that is the pretty title which the professors have been so polite as to give us, instead of leaving us simply our proper name of man. Yet it would have been very easy to do this, seeing that we are the only family, the only genus, and the only species of the order. In railway travelling, people of distinction have a reserved carriage to themselves: so we decidedly deserve an order to ourselves; but that is not quite the same as a separate kingdom. In short, you are a *bimane;* so make the best you can of it.

Order 2. *Quadrumana* (*four-handed*).

These, as their name indicates, have four hands: two at the end of the arms, and two at the end of the legs; such are the monkeys. There is nothing to remark; they are all alike. Stay; I am wrong, though: there is something, insignificant it is true, but still pointing to deviation. In some the canine teeth are set forward, *i. e.* project, and are longer than the rest, and some species, as the ape, for instance, have just under their cheeks convenient little pockets, which open into the mouth, and in which they can deposit a reserve of nuts to be devoured at leisure; these are called *pouches.*

It is a trifle in itself, but we have here a first example of the eccentricities of nature in the construction of animals. At one time she adds a detail; at another she suppresses one. Sometimes she is pleased to enlarge an organ, as in the canine teeth of the monkey; sometimes she reduces it; or perhaps here she makes its construction more simple; there again more complicated: but still it is always the same organ. So the dressmaker shapes the sleeves of a dress, sometimes open, sometimes closed, flat or puffed, plain or ornamented, pagoda-shaped or gigot-formed: but still they are all of them sleeves.

Order 3. *Cheiroptera* (*wing-handed*).

I am quite ashamed of offering you such a word as this, my dear child. It was a Greek fancy of the learned men, who would not condescend to use the vulgar name Bats. In the Greek, *cheir* means hand, and *pteron* wing. The Cheiroptera are animals with winged hands; in fact, the fingers which terminate the fore-limbs of the bat lengthen as they spread out to an extravagant extent; and are connected together by a membrane springing from the body, with which they beat the air as with a wing, and which enables them to fly with such ease that they are often taken for birds.

But, so far from really being a bird, this curious little creature has the same internal organization as ours, and indeed comes so near us, though without looking as if it did, that a scientific man, and a very distinguished one too, placed the bat in the first family of the animal kingdom, with the monkey, and, you will hardly believe it, with man. It is found that the bat, like man and the monkey, suckles its young at the breast; and it was this very character which Linnæus, the leader of artificial classification, thought of selecting as the distinguishing mark of his first family in the animal kingdom. It is true that in honor of the human race he had given that first family a much more sonorous name than our usual one of *man*—viz. *primates*, the first in rank—that is, the princes. But, alas! we were to be princes on an equality with bats; and, for my own part, I prefer being a *bimane*, and alone. I really believe that it was to put this saucy little creature back into its proper place that, at the time of the great revolution in favor of natural classification, the conclave of professors assembled at the Botanical Gardens in Paris inflicted this horrid name of Cheiroptera on the bat, ejecting it contemptuously from the overthrown dynasty of the *primates*.

I have not been sorry to make you acquainted as we went along, with this little trait in the history of classifi cation ; but beyond it there is really nothing particular to say about the apparatus for the nourishment of the deposed bat-princes, which is a plain proof how nearly it must be like our own. By-the-by, there is one trifling remark to be made with regard to her teeth. The bats we have in our country (France), for there are many varieties of species in the world, live on insects, which they catch in their flight by night. These insects are often enveloped in a very hard outer case, which molars like ours would have some difficulty in chewing properly ; consequently the molars of our little friend are fringed with conical points, and with these she grinds down her prey without difficulty.

In America there is a large bat, the vampire, which lives on the blood of animals, and nature has armed it accordingly. It has at the extremity of its muzzle two sharp beak-like incisors, like the lancets of a surgeon. The vampire bat, which roams by night like other bats, goes straight at the large animals it sees asleep, delicately opens a vein in the throat without waking them, and sucks their blood in long draughts, taking care, by fanning them with its wings, to lull them into a cool and balmy slumber. It does not, as you see, make a savage attack on its victim : it merely inflicts a bite like that of the leech, but the result may be death. This is the best emblem I know of the sycophant, who undermines your soul while he fans your vanity ; and observe, while we are on the subject, that this species has always had the art of insinuating itself among princes.

ORDER 4. *Carnivora* (*flesh-eaters*).

When translated into English, this word needs no explanation. And here we have the tribe of bears, wolves, foxes, weasels, dogs, cats, tigers, lions, of all the fighting animals, *i. e.*, those which steep their muzzles in blood, and live by devouring others. These have a similar apparatus for nutrition to our own; especially the bear, who, with the monkey, is the animal most nearly resembling man, seeing that he has feet like ours, with scarcely any tail, while the monkey has our hands, without specifying any other points of resemblance. Like ourselves, too, the bear is omnivorous; that is to say, it eats everything, vegetables and fruit as well as meat; and nature, which has given it our diet, has furnished it with molars almost exactly like our own. Its canine teeth alone differ from ours: they are more prominent even than those of the *quadrumana;* and this is the case with all the members of the order, in whom we find them sometimes developed into actual daggers. But those of them which are purely carnivorous have molars peculiar to themselves. The lion, for example, who does not share the bear's taste for carrots, and who would die of hunger surrounded by the honey and grapes of which the bear is so fond—the lion, who never takes anything but raw meat between his teeth, has molars furnished with sharp cutting edges, intended to slice the meat like the chopping knives used by cooks for making a hash.

The lion offers another peculiarity, which is common to him with all the *Carnivora.* Place your finger close to the lower end of your ear, and work your jaw; you will feel something hard moving backward and forward against your finger. This is where the lower jaw is set into a bone of the skull, called the *temporal,* if you care to know its name; in other words, the bone of the temple. The extremity of the jaw bends, and forms a kind of little knob, called *condyle,* which fits into a cavity of the temporal bone. With us the cavity is not very deep, nor the knob very large, so that it can play very freely; and it is this which allows us that second movement from side to side, of which I spoke to you formerly, and thanks to which, our little mills reduce a mouthful of bread into paste. But this freedom of action has also its inconveniences. You must never attempt to force too large an article into your mouth at once—an apple, for instance—the efforts you would then be obliged to make might easily cause the *condyle* to slip out of its little cavity, where its hold is but slight, and to get under the *temporal bone;* and there you would be with your mouth wide open until the doctor arrived. The lion, whose voracious jaw opens like the door of an oven, so that the tamers of wild beasts have no scruple in thrusting in their whole heads, a mouthful a good deal larger than an apple; the lion, who has no doctors, would often be liable to this accident—an irremediable one in his case—if nature had not made a special provision for him. In order to secure greater firmness and strength, the second movement is in his case sacrificed by embedding the *condyles* deeply in their cavities, where they are fastened in such a fashion that they can only move up and down, like the handles of a pair of pincers. This is a restraint which enables the jaw to be safely thrown open as wide as the fiery impulse of its terrible proprietor impels it. Less freedom, in exchange for more power, is a bargain which any one would gladly accept who plays the part of a lion!

I have here a remark to make. We have now passed in review three orders besides our own, and have only had to point out a change in the fastenings of the jaws and in the teeth; and you will find that the same sort of modifications take place in the whole class of mammals. This is in fact the essentially movable and variable point in their apparatus for nutrition. The jaw and its weapons vary their character from one species to another, according to the nature of their food; but the modifications generally terminate there, *i.e.* on the threshold, as it were. The interior arrangements of the house remain otherwise much the same in all.

Here, however, in the lion, there is an interior change to be described; but not in the arrangement of the parts, only in their size; the stomach in this species being even smaller and weaker in proportion than ours, and the digestive tube more than twice as short. The digestive tube of an ordinary sized man is about seven times the length of his body, whilst that of the lion only measures three times the length of the animal. This is a natural consequence of the kind of nourishment he takes. Flesh and blood, on which he lives entirely, is concentrated *albumen*, prepared beforehand in the bodies of his victims; so that no great preparation is needed here to convert it into lion's blood. A professor of chemistry, who has a good assistant, does not need a very large laboratory. This is the case with the lion; and nature, which makes nothing in vain, has here economised space. Tame the monarch of the forest into a domestic animal, and change his food, and I will wager anything you please that, in the course of a few generations, his digestive tube will lengthen itself. Examine the inside of the cat, his little cousin, formed originally on the same pattern as himself, and, without having ascertained the fact myself, I am sure that, by dint of feeding it daily on sops and milk from generation to generation, its digestive tube has become more than three times the length of its body.

Here you ought to be told at once a very important fact relative to the organization of the lower animals, one which places them all very far below the order of *Bimana*, since there is such an order. In bestowing intelligence and freedom of action on man, the Almighty has given him the unspeakable privilege of working in His footsteps—if I may presume to use the expression—of following up His work of creation as it came from His hand. Now especially that man begins to see a little more clearly into the laws of life, he has entered more directly into the possession of this almost divine privilege, which the Almighty has graciously vouchsafed him. You can even now have an ox or a sheep made to order in England, giving your dimensions, as if you were ordering a cabinet ; and in a few years, if you have not asked actual impossibilities, your commission will be executed to within an inch. This is not said in reference to the *Carnivora*. But in bidding you good-bye, my dear little mammal, I could not bear to leave you under the weight of that debasing title : I wanted also to show you your greatness.

LETTER XXXI.

MAMMALIA. (*Mammals*)—*continued.*

Let us continue to pass in review the different orders of the class Mammalia. We may meet elsewhere with facts more important to science, but nowhere with any so personally interesting to ourselves.

Order 5. *Insectivora* (*insect-eaters*).

This order devours insects, as their name tells you plainly enough. They feed in the same manner as the bats; consequently they have molars like theirs, as was necessary. It is an unimportant little family, and we will not waste much time upon it. The chief of the order is the hedgehog, a native of our country—not very large, about nine inches long—which lives in the woods, and which when rolled up into a ball, with all its quills standing out, looks very much like an enormous horse-chestnut in its shell. Its canines have not much work to do, consequently they are very small; but, on the other hand, its two front incisors are prolonged beyond the others, the better to seize its prey, which creeps upon the ground. Internally there is nothing to remark upon.

Next to the hedgehog I will mention as a curiosity the shrew or sand-mouse, which, in spite of its name, is no mouse at all, but has the honor, if honor it be, of being the smallest animal known of the class Mammalia.

It is about two inches in length altogether; and if you carefully examine its little body, you will find that it contains all the organs you possess yourself—œsophagus, stomach, liver, intestines, veins, arteries, heart, lungs—nothing is wanting: the machinery is absolutely the same.

ORDER 6. *Rodentia* (*rodents*).

Were we to translate this word into its meaning, namely, the *Gnawers*, there would be some comfort in it, for we would at once know what it means: but no matter. Rodents, or Gnawers, are rats, hares, rabbits, beavers, marmosets, squirrels, in fact all the creatures which *nibble*. To *nibble*, if you do not exactly understand the word, means to chew with the points of the teeth. The rodents have no other way of eating but by filing, if one may so say, their food with the points of two incisors with which both the jaws are provided; these incisors are very long, much longer even than those of the hedgehog. The next time you see a rabbit at table, ask to see the head; and you will find that it has four pretty little teeth, very sharp, shaped like a joiner's chisel; that is to say, with a "bevelled edge," to use the received expression; in other words, with one edge thinner than the other.

Here, then, we begin to diverge from the old model. First, there is a different fastening, or *articulation*, as it is called, of the jaw. Its *condyles*, which we saw just now in the *Carnivora* enlarged transversely and deeply embedded in the *fossæ* or cavity of the temporal bone, extend here longitudinally; an arrangement which enables the jaw to move backward and forward at pleasure, like the arm of the locksmith when using the file. Furthermore, those little teeth, which are constantly rubbing against each other, would be very soon worn out, if, like our own, they were made once for all; accordingly their germ, or *pulp*, to use the proper term, instead of perishing, as with us, when the tooth has once come, retains its life, and works on throughout the life of the animal. They sometimes say of a man who has not eaten for a long while, that his teeth have grown long. This is a joke with us; but in the case of a *rodent* would be too serious a matter to be a joke; for, as their incisors are always growing, like our nails, they would soon become too long if the animal ceased for any length of time to wear them down by eating. It is for this reason that rats and mice have such incessant appetites, and that with them "all is fish that comes to the net;" old books, rags, and even planks of wood, which they will gnaw for want of something better. Come what may, they must keep up at an equal rate the wear and tear of the incisors, and the internal growth of the pulp beneath, which is always pushing the tooth forward. This dull continuous work might otherwise have a terrible result, which you would never suspect. It is very disastrous for a young lady to lose a front tooth, as it is called, for it sadly spoils a pretty face; but for a *rodent* such a loss is much worse; in fact, it is a death-warrant. The corresponding tooth, having no longer anything to rub against, ceases to wear out; and as it does not stop growing on this account, it lengthens indefinitely, until at last it pushes out beyond the mouth, and places itself like a bar between the two remaining teeth and the food of the animal, who, poor beast, being unable to eat, ceases to live.

The canines, whose duty it is to pierce the food, have, of course, no use in a jaw that grinds, nor are they to be found there. Between the incisors and the molars there is a large vacant space, which you will easily detect if you examine a rabbit's head.

Finally, animals which can fall back in time of need on a plank for their dinner, require a very different-sized cooking apparatus to that of the *Carnivora*. Thus the rat, the most perfect sample of the rodent order, possesses a digestive tube of a prodigious length, through which the scrapings of wood have plenty of time for travelling, while the minute nutritive particles they contain are being thoroughly disengaged; and as every part of the animal organization tends towards keeping our insatiable rodents in the constant state of voracity required by its inexorable pulps, nature has given it an enormous heart whose size exceeds even that of its stomach.

Perhaps you do not catch at once the connection which exists between the size of the heart and of the appetite; yet it is very simple. Large barrels are requisite for those who brew a great deal of beer, and large hearts for those who make a great deal of blood. Now, it is the blood, as you know, which carries heat; in other words, life, throughout the body; when it pours in in torrents, the fire goes twice as fast, and, consequently, the feeding must be kept up. A medical friend of mine told me that he once had some rats sent to him—a boxfull in fact—for one of those scientific experiments which one would venture to condemn more earnestly if their results were not sometimes beneficial. Next morning there were only two or three animals to be found, and these had eaten up the others. See the consequence of having too much heart!

ORDER 7. *Pachydermata* (*thick-skinned*).

In Greek *pachus* means thick, and *derma* skin. *Pachyderms*, therefore, are thick-skinned animals. It is rather a vague denomination, as you perceive, and does not tell us much about them; but it appears that it was not very easy to find a better term. For my own part I should be very much puzzled to find a name really suitable for such an irregular company as this, in which all the huge beasts of the earth—the elephant, the rhinoceros, the hippopotamus—are heaped one upon the other, side by side with the horse, the ass, and the hog; begging your pardon for an ugly word.

All these creatures live on vegetables, with the exception of the hog, to whom nothing comes amiss; or who, in other words, is *omnivorous*, like the bear, and also another member of the class *Mammalia*, which I do not name for fear of making you blush at your companionship. This assures you that, in the order of the *Pachydermata*, the digestive apparatus is very fully developed. The horse, for instance, has a very voluminous stomach, which extends much farther back than the point at which the œsophagus empties itself; and in which, on close examination, a sort of contraction is observed which appears to divide it in half, producing the false effect of there being two stomachs. But, after all, we do not find, even in this case, any essential difference to remark upon in the internal arrangements; it is always the teeth we must look at if we want to have something to say. There, indeed, we have only to choose; nature has indulged herself in all manner of fantastic freaks.

To begin with the elephant, the grand master of the order, he presents us with one of the most oddly-furnished jaws in existence. Every one knows those two enormous tusks which protrude from his mouth, and which furnish human industry with nearly the whole store of ivory it has need of. Those two teeth are the largest, beyond comparison, of any in the animal kingdom ; yet they are two merely ornamental teeth, perfectly useless in the operation of eating, and very ruinous into the bargain to the proprietor. All those stores of the blood which furnish the materials for ivory pass into these tusks, and, as often happens to people who give way to a taste for luxuries, there is nothing left wherewith to provide the animal with serviceable teeth. Those tusks of the elephant are nothing but his upper incisors, the only ones, observe, which curve in coming out of his jaw. In the lower jaw he has no incisors at all ; canine teeth are entirely wanting ; and by way of dental apparatus, this meagerly-furnished mouth possesses on each side of either jaw one or two molars, enormous in size, but not of ivory. They are composed of a number of enamelled upright layers of tooth-substance (*dentine*), soldered together with a bony cement ; and these are our giant's only resource for chewing the grass, young shoots, and leaves of trees, which are his natural food.* As a consolation, he has the glory of knowing that he possesses the very finest teeth in the world, the terror of all who approach him ; and I can compare him to nothing so well as to a vain woman, who is contented to live on potatoes that she may wear fine clothes and excite the envy of her neighbors.

The hippopotamus also has incisors in the upper jaw, which curve as they come out of the mouth; but these never attain anything like the size of the elephant's tusks, neither do they hinder the development of the other teeth, of which this animal has a very respectable collection. The upper incisors bend downward; those in the lower jaw stand out horizontally, and terminate in sharp points like plough-shares; and indeed the hippopotamus uses them for tearing up the ground in order to get at the roots which form its nutriment. These are, besides, formidable weapons, witn which when enraged the animal can tear even boats in pieces; for, as you are aware, the hippopotamus is almost amphibious, and browses on water-plants, and lives in the great rivers of Africa, its native country. Its name alone would have told you this had you understood Greek;* but I have no complaint to make this time, for it was the Greeks themselves who gave it. You would find it very awkward, would you not? if you had to breakfast at the bottom of the Thames, and could not swallow a morsel without having your nose filled with water? But the hippopotamus labors under no such inconvenience. Its nostrils are provided with two little doors, which it closes at will, and behind this screen the lungs keep quite quiet while the animal goes backwards and forwards in the water. There is generally a hippopotamus in every large menagerie. The next time you visit one look at him. You will see him with a large stomach almost trailing on the ground: and no wonder; he needs plenty of room in which to stow away all the canes, reeds, and water-plants from the bottoms of rivers, which are not very nutritious food. Accordingly the stomach of the river-horse presents the appearance not only of two compartments, like that of the true horse, but looks as if it were divided into three or four.

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* These teeth are nevertheless very efficient grindstones

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* ἱπποϛ a horse, and ποταμοϛ a river. The Greeks, who had seen the hippopotamus in the Nile, in Egypt, named it the river-horse as afterwards the Romans called the elephant the ox of Lucania, because they first saw it in Lucania during the war with Pyrrhus.

To conclude my account of this animal, I must add that the ivory of its teeth is even more beautiful than that of the elephant's tusks, and that dentists carve it into very magnificent teeth for their patients. This is not a matter to interest you much at present, but we never know what may happen. I advise you, however, never to make use of hippopotamus's teeth; they turn yellow very quickly, and, when people are driven to buy teeth, the least they can try for, is to get good-looking ones for their money.

I should like to say something about the rhinoceros while we are on the colossal tribes, but it is a very unsatisfactory subject. The animal has no canines, sometimes no incisors even; sometimes it has as many as thirty-six teeth, according to the species, as naturalists aver; and this is all I have to say about this great lump of flesh, so misshapen outside, yet so regularly formed within. He it is who especially deserves the title *pachydermata*, his skin being so hard and thick that bullets glance off its surface. But this has nothing to do with our present subject, any more than the horn upon his nose, whose turn for description may come if I ever give you the history of the skin and all connected with it.

The hog also has canines, and very strong ones; but it is in the wild state, when it is called a boar, that these appear in their real form. There we find them projecting out of the mouth with a curve, as is so commonly seen among the *pachydermata*, forming those terrible, sharp, and pointed tusks which have been so often fatal to the hunter. The wild boar of the forest is supposed to be the original ancestor of the domestic pig; and if, as is probable, this is really the case, we have here a remarkable instance of the effect of man's treatment upon the organisation of the animals he collects around him. The wild boar lives only on fruits and roots, which, like the hippopotamus, he tears up with his tusks, those safeguards of his, amid the many perils of his life in the woods. In the service of man, on the contrary, he becomes lazy, cowardly, and greedy; unlearns his energy and combativeness, eats all that is offered to him in the trough, even meat, when it happens to be thrown in; and, in order to do this more easily, has recalled toward his mouth those formidable war-tusks of his, so tremendous as weapons, so useless as teeth; has, in fact, turned his sword into a fork. It is the case of a Tartar degenerated into a Chinaman.*

This suggests to me an idea relative to the horse, the last important member of the *pachydermata* which remains to be spoken of. It also has its canines, but very small ones; they disappear, so to speak, in a large vacancy between the incisors and the molars, where man inserts the bit, by means of which the animal has been subdued. Small as these are, however, these canines indicate that the horse might eat flesh, canine teeth being the distinctive attribute of the carnivorous mammals. I have read somewhere, but I do not remember where, that an unusual development of strength could be produced in the horse by feeding it on flesh; and the old Greek poets write of a king† in the barbarous ages who gave his horses, men for food. If I knew some rich professor who was inclined to spend money in the investigation of a curious fact, I would advise him to set apart a sum for putting horses on a meat diet, from sire to son, gradually increasing the quantity ; and I would boldly warrant that in the course of successive generations the canines would become so large as to impede the entrance of the bit into the mouth, and, moreover, would make it rather a ticklish office for the groom to place it there. But let us set aside the teeth the horse might possibly have, in order to examine those it has already. There are six incisors in each jaw ; these are long and rather projecting teeth, by examining which, the age of the horse can be detected from certain marks which appear in them from year to year. The molars are flat, square, furrowed with bars of enamel, marking out more or less distinct crescents ; perfectly constructed, in short, for chewing hay and oats. Nevertheless, I should never be surprised to see the enamel crescents become sharp-cutting in our rich professor's stable ; so skillful is the unseen Architect who created animals, in altering the house when the tenant changes his habits.

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* China, about which we have heard a great deal of late years has been several times invaded by the warrior hordes of Tartary But at each time, unto the second and third generations, the vanquishers have taken the effeminate manners, the costume and the usages of the vanquished, and so many conquests have only resulted in converting millions of Tartars into Chinese.

† Diomed, King of Thrace.

ORDER 8. *Ruminantia* (*ruminants*).

I shall retain through life a pleasant recollection of the *ruminants*. Through them I obtained the first prize for natural history which was ever given in France to the pupils of the learned university. It is thirty years ago since this happened, and I own, without any false modesty, that even now the word *ruminant* rings very agreeably in my ear. It reminds me of one of the proudest moments of my life, of the honor done to me by the illustrious Geoffroy St. Hilaire, when he called me, a little college urchin, up to him, that he might have a nearer view, as he said, of the baby-professor who had spoken so well on ruminants. Yes, it is more than thirty years ago, for alas! it was in 1831. There needed no less an event, as I have told you before, than the revolution of 1830 in France to induce the big-wigs of education to sacrifice two hours per week in one class to the study of natural history. Yes, my dear child, it is only that short time ago since natural history became one of the subjects of study in French colleges; and the gray-haired men of the present day finished their education, as it is called, without having learnt a single word of what I am now taking the trouble to teach you, a mere child. You see you have come into the world just at the right time, and will be able to instruct others in your turn. But before giving lessons to other people you must first finish learning your own. Forgive me this involuntary reference to a happy time when I was not much more rational than you are. And now, let us return to our ruminants—those dear, good beasts, the nourishing fathers of the human race.

LETTER XXXII.

MAMMALIA—*continued.*

ORDER 8. *Ruminants—continued.*

EVERY created thing has an appointed part to perform; but there are some mysterious parts of which we cannot understand the drift. That of the ruminants, however, is so clearly marked out, that we detect it at a glance.

To qualify myself for supplying your young mind with the food I am going to offer it to-day, I have been obliged, my dear child, to browse in a good many books of which you could have understood but little yourself; and I have been forced to ruminate a long time upon what I have read, and to digest it slowly in my head, which I may say, without vanity, is of larger capacity than yours; no great wonder at my age. Now, if I have succeeded in my undertaking, you will benefit by all the work which has been going on in my mind for the purpose of feeding yours without over-fatigue to it; and I shall almost have the right to say that its nourishment has been derived from me. My lamp could tell you what it has sometimes cost me to supply a single page which might instruct, without repelling you.

Now, this is precisely what the *ruminant* does. The part he has to perform is to collect in the meadows a sort of food, which would disgust less well-organized stomachs than his own, to work it well up within him, and to give it back in a more palatable and less indigestible form. The little flesh-eaters (*carnivora*) come afterwards to the feast, and the feast is himself!

The whole history, then, of the ruminant is to be read in his stomach. His real office is to digest, and in fact he devotes the best hours of his days to the perfecting of that beneficent labor, on which the life of so many weak stomachs depends. Have you ever amused yourself by watching a large ox lying down in a meadow? Long after he has finished grazing, his jaw continues to work, turning round and round like the grindstone of a painter when he is rubbing down his colors. Look, and you will see that he will remain there for hours together, motionless and contemplative, absorbed in this incomprehensible mastication, rolling about in his throat from time to time some invisible food. Do not laugh at him, however. As you see him there he is performing his part in life, he is *ruminating.*

To ruminate is to chew over again what has been already swallowed; and, however droll this may seem to you, it is the business which all ruminants are born to. You remember the monkey's pouch, which serves him as a larder, whence he takes out his provisions as he wants to eat. The ruminant has an immense pouch of the same kind, into which, while he is grazing, he hastily conveys large masses of half-bitten grass. You probably think he is eating when he has his head down in the grass; but you are mistaken. This is only a preparatory work; he is hastily heaping up in his larder the food he intends to eat by-and-by; only his larder, instead of being, like the monkey's, in his cheeks, where, indeed, there would not have been half room enough for those great bundles he tucks in, is in the middle of his body, close to the extremity of the œsophagus, whose lower wall, being slit at that part, becomes an imperfectly secure tube, ready to burst open under pressure, and allow the food to escape between the edges of the slit; these, otherwise, remaining naturally closed. As soon as the large bundles of grass come to this part, they press against the walls of the tube, which they by this means separate, and fall into the provision-pouch, which bears the name of paunch, or grass-pocket, in fact. As soon as the paunch is well filled, and the animal sure of his dinner, he lies down in some quiet corner, where he proceeds gravely with the important act, which is the real object of his existence. A little below the entrance to the paunch, and communicating both with it and the canal of the œsophagus, is a second receptacle, which old French naturalists, not being much acquainted with Greek, named the *cap*, on account of its fancied resemblance to the caps worn on the head, and which we call 'king's hood' or 'honey-comb bag.' This second stomach now contracts (at least so it is supposed), and thus retains, as if with a closed fist, a portion of the grass accumulated in the paunch: of this it forms a pellet, which it sends back into the œsophagus, and the œsophagus, by continued contractions from below upwards, returns it to the mouth, where at last the grassy lump is chewed in good earnest, and to some purpose. There is no necessity for hurry; the ruminant has no other business on the face of the earth but this, and thus hour after hour passes away, the food pellets rising one after another to the onslaught of the teeth. Nor do they go back again until they have been reduced by long mastication into an almost liquid paste, which glides through the œsophagus without forcing open the slit, and falls straight into a third pouch, called by old Frenchmen the *leaf*, on account of certain large folds, somewhat like the leaves of a book, which line the interior; and known to us as the *manyplies*. From this stomach, No. 3, this grass-pap passes into a fourth and last bag, which is the real stomach, and where the final work of digestion is accomplished. This fourth pouch also has a pretty little name of the old-fashioned sort, like the three others; it is called the *reed* or *rennet-bag*, from the property it possesses, in the calf, of turning milk into curds: and of his four stomachs this is the only one which the ruminant makes use of at first. As long as the young animal is nursed by its mother, the other compartments remain inactive and small in size; they neither grow nor exercise their functions until it begins to eat grass. Indeed, they would probably entirely disappear, if any one would go to the expense of keeping the animal on milk all its life. If it ceased to have anything to ruminate, nature would certainly lose no time in relieving it of its useless workshop of rumination.

As it is right to give every one his due, I will mention that we owe our accurate knowledge of this simple and ingenious mechanism of *rumination* to the labors of Flourens, a scientific Frenchman, who is still alive, and who has made a great many interesting inquiries into the subject we are now considering, *i. e.*, the life of animals. He is a very clever man into the bargain—so perfect a master of his own language, that the French Academy has felt itself justified in opening its doors to him—an unheard-of honor for a member of the Academy of Sciences. And yet, in spite of all this, I heartily congratulate you that the discovery of the *paunch*, the *cap*, the *leaf*, and the *rennet-bag*, was not delayed for his arrival. He is just the man who might have been tempted, in his capacity of profound scholar, to have hunted up for them *in the Jardin des racines grecques**; four magnificent names, which would only have bewildered you.

Beyond the rennet-bag there is no change of conformation to note, except that the intestinal tube is naturally much longer than ours, on account of the difference of food: as a general rule, it is ten or twelve times the length of the body. The sheep, who is able to pick up a living in the poorest pastures, is indebted for this inestimable power, which makes him the special blessing of dry and barren countries, to a still further peculiarity of organization; with him the intestinal tube is twenty-eight times the length of the body.

We have seen among the *Carnivora*, whose jaws have so much work to do, that the condyles of the jawbone are sunk deeply into the fossa of the temporal bone. The ruminant, whose peaceful mouth is formed for contending only with grass, is organized quite differently. Here the condyle is flattened, and the fossa of the temporal bone very shallow, presenting to the condyle an almost flat surface, so that the jawbone is enabled to revolve with ease for the better mastication of the pellets of grass. This conformation is also to be seen in the *pachydermata* who feed upon vegetables. In the horse, especially, whose food is almost the same as that of the ox, the *articulation* (as this joining of the condyle to the temporal bone is called) of the jaw, is also nearly identical; and it is the same with the teeth, with very trifling variations, those of all ruminants are constructed on the same plan as in the horse. The canines only require a separate notice.

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* Your brother can tell you about the *Jardin des racines grecques*. It is a charming little book, of which every generation of collegians has learnt, by heart, the commencement; but I have never known one, even among the most intrepid, who had ever been to the end of it.

But first I must tell you that, by some special privilege, the reason for which I do not undertake to explain, the order of ruminants is the only one containing animals with horns on their foreheads. Stags, goats, reindeer, chamois, gazelles, roebucks, oxen, buffaloes, all the beasts with horned foreheads, belong to the ruminants. Indeed, this fact would form a very convenient mark of distinction between them and other animals, were there not exceptions to it. Some ruminants have no horns ; and then, as if in compensation for the deficiency, we find them provided with canines in the upper jaw, in addition to those below.

The ruminant which has the most beautiful canines is the musk-deer, a pretty little animal inhabiting the highlands of Central Asia, like the chamois of the Alps. But now that you know who he is, you will probably often be tempted to wish he had never existed ; for it is from a small pouch below his belly that people obtain that odious musk of which Oriental beauties are so fond, and which even certain strong-nerved ladies of our own country are guilty of using in public, to the great detriment of general health. But enough of this ; our business is with the canines of the musk-deer. They project with a descending curve from the upper jaw, and would give the animal the very false appearance of a small wild boar, but for the great delicacy of its legs, which are more slender than even those of our roebuck, to whom, with the exception of the horns, it bears a close resemblance, as its name implies.

After the musk-deer comes the large family of camels and llamas, which represent—the former in Asia and Africa, the latter in America—the irregular groups of ruminants which have canines instead of horns, and which seem to be placed as intermediates between true ruminants and the pachydermata. They form the connecting link between the horse and the ox, and men prefer employing them as beasts of burden to using them as butcher's meat; though one could eat them in their own country with less disgust than Europeans feel in making a meal of horseflesh; so that they might be a very acceptable resource in many cases. The real fact is, that ruminants with horns and without upper canines have more delicate flesh than the others, and seem more especially destined to be eaten. Yet if one had only to look at the stomach, which is, after all, the distinctive characteristic of the order, camels and llamas would stand in the first rank as ruminants. Besides the usual character of four stomachs, their paunch and honeycomb-bag are furnished with lage cells which act as reservoirs, and fill with water whenever the animal has the chance of drinking freely, and from whence in time of drought he draws it up into his mouth and swallows it. This is what makes the camel so valuable to the wandering tribes in the great deserts of Africa and Asia. He is the only animal who can pass several days under the burning sun of Sahara without drinking—or rather without appearing to do so—for he carries his provision of water concealed from all eyes in the recesses of his body. I dare say you have often heard stories of Arabs dying of thirst who have opened the stomachs of their camels in search of a last draught of water. It must be a terrible thirst to drive a man to such an extremity; for, as you may imagine, one could not expect the water there to be either fresh or clear, to say nothing of the great risk there would generally be of finding the reservoir empty. Such an extreme is never resorted to till water has failed for a long time, and all the goat-skin bottles have been emptied ; and in such a case it is but too likely that the camel has followed his master's example, and emptied his water-skins for his own use. But this is only half the internal fittings of the "ship of the desert," as the Arabs call him. In the desert it is often as difficult to find food as water ; and nature has equally provided for this. The hump you see rising upon the camel's back in your picture-books is his safeguard against starvation. It is a huge mass of fat. I need say no more. You will remember Mr. Liebeg's pig, which lived 160 days upon its own bacon. Without going quite such lengths as that, the camel can keep up his fire for a long time upon the fuel which the blood obtains from this blessed hump. Since we are talking of this animal, and he takes a remarkable place in a history of nutrition, I ought to tell you that camels are classed into two families by their hump : there is the camel, properly so called, which has two humps, and the dromedary, which has but one. This latter did not require such a supply of provisions as the other, for he is very much swifter of foot, and consequently his journeys are more speedily performed.

I have nothing particular to say to you about the other ruminants, in the matter of their organs of nutrition ; but I will not quit the subject without reminding you of one thing which concerns nutrition, not theirs, however, but ours. It was by the taming of the domestic ruminants—that unfailing dinner-material which now follows everywhere at the heels of his master—that human civilisation began. Before that event, man, driven to depend for his living upon the hazards of the chase, spent his whole time in seeking for food, and had none to spare for the pursuit of any other branch of industry.

Far as we may ascend in the history of ages we shall find shepherd races. Beyond them there is no history at all, nor could there be. The first leisure hours of man, and, consequently, his first efforts in art and literature, date from the period when the ruminant animals, those special fabricators of nutritive aliments, were gathered around mankind, and worked out their destiny under the shadow of his tent, by his direction, and for his benefit. But all this is so distant from us now, that it is scarcely worth the trouble of thinking about. The human race is somewhat like those old people who have lost all recollection of their childhood; and young people are not required to know what their elders have forgotten. It is well, however, that they should not be quite ignorant on the subject. When you hear that the Society for the Prevention of Cruelty to Animals has taken up the cause of some barbarously-used ox or sheep, do not turn it into ridicule. Those humble species have supported ours from the first; and you should recollect, now and then, that human society made its first step forward when it began to keep flocks and herds.

LETTER XXXIII.

MAMMALIA—*continued.*

We come now to animals less familiar to you, and none of which inhabit Europe. We shall therefore pass more quickly over them.

Order 9. *Marsupialiā* (*pouched*).

Marsupium is Latin for purse, pouch, or pocket. The marsupials are distinguished from other animals by a pouch which the mother has under her belly, and in which the little ones take refuge at the slightest alarm. You would be very much interested with their whole story; but it has nothing to do with our present subject, which we should soon lose sight of if we once began to wander away. This order, so easily distinguished otherwise by that singular pouch, unfortunately for us, offers nothing new for observation. It includes several species, differing entirely from one another on the subject of nutrition, and closely resembling some already described. Some are both carnivorous and insectivorous, and are therefore armed with powerful canines, and with molars like those of the hedgehog. Others are herbivorous, like hares, and have almost the jaws of a rodent. Among the former we have the opossum, celebrated by Florian in one of his prettiest fables. The opossum inhabits South America. Charming little marsupials are to be found in the Molucca Isles, whence come the nutmeg and the clove; these are very like our squirrels, and live as they do, in trees, hunting after fruit and insects. But the greatest number of marsupials belong to Australia, the real native land of the order. They form by far the larger portion of the mammalia with which that country is enriched; the most celebrated amongst them being the kangaroo; an animal which is now becoming common in European menageries, and which, excepting in the matter of its pouch, is nothing but a magnified rabbit, as tall as a man, and with a tail almost as long as itself. As a rabbit, you know what its eating apparatus must be; and some day, no doubt, the French Acclimatisation Society will enable us to judge of its flavor. It is a kind of meat very likely to be seen on our dinner-tables by-and-by; and, as you have plenty of time before you, probably you may eat of it before you die.

ORDER 10. *Edentata* (*toothless*).

These come more directly within our limits. They are classed according to their teeth; yet if their name were to be trusted, they ought to have no teeth at all. Whereas, alas! almost all of them have some, and I am heartily ashamed of their scientic designation; but how can we help it? The only really *Edentata*, *i. e.* toothless animals, amongst them are the ant-eaters, who, considering the nature of their food, are not much in want of teeth. They feed among the ant-hills, whence they get their name; and as they are a tolerable size (from two to three feet in length), it would really have been quite a hardship upon them to have been forced to crunch the ants one by one at every meal. To get on rapidly they catch them with their tongue; but what a tongue! Imagine a kind of long earthworm, lodged in a snout which is elongated like a bird's beak, and has a very small opening at the extremity. The ant eater inserts this long, string-like tongue into the crowded ranks of its victims, and, as its surface is glutinous, they stick to it by hundreds at a time, and are swallowed at one gulp without a chance of escape. This tongue, perfectly unique in its character, stretches out in its murderous exertions to nearly three times the length of the animal's long head. What a distance there seems between such a tongue as this and your own litle door-keeper! But no wonder: we have now reached the confines of the kingdom of *Mammalia*, and the face of nature is beginning to change.

The Armadillo, for instance, which comes next to the ant-eater, looks far more like the tortoise or lizard than its noble mammalian brethren. It is covered with scales; and, to look at it, you would say it was a reptile, in spite of its higher internal organization. As for teeth, it has certainly enough of them to give the lie to its name of *edentata;* but they are not very serviceable ones. They are called molars, however, because they are situated in that part of the mouth which is always assigned to molars; but they are miserable grindstones, very unlike any of which we have hitherto treated. They are all of them flattened cylinders, with no enamel bars to strengthen them; are small and poor, and are placed at rather wide intervals from one another. The poor armadillo munches with these, as best he can, slugs, tender roots, and other prey of the same sort, with which he is obliged to content himself, and which do not require very formidable tools.

The most questionable member of this class is the Unau, or Two-toed Sloth. It only wants incisors to be as toothless as ourselves! and the first time I saw it I took it for a little bear. It is true I was then younger than you are now; for the bear, who is one of our nearest neighbors, ought not to have been confounded with the unhappy being before us, one of the drudges of the animal creation; though M. de Blainville (who had not my excuse) proposed placing it still nearer to us, namely, amongst the *Quadrumana*. Observe that instead of hands it has at the end of its fore-limbs only two enormously curved claws, which have somewhat the appearance of a gigantic fork accidentally twisted. Accordingly its illustrious sponsor offered it to the world as an *irregular quadrumane*. I believe so, indeed! This *quadrumane* without hands—this *edentate* whose molars are preceded by magnificent canines—this enigma of nature, created for the confusion and despair of all classification—does, I must in all humility confess, completely upset the rule I laid down so stringently when speaking of the horse, as to the objects for which canine teeth were framed. The canine teeth of the sloth are more developed than its molars, and yet I cannot tell you what they are there for at all. It feeds upon the leaves of trees; and old travellers in South America, where it inhabits, have told us that, when it has once hoisted itself up a tree, it will strip it to its last leaf, and afterwards drop to the ground to avoid the trouble of crawling down. This was what first obtained for it the villanous name of sloth, a title which is certainly justified by its gait when on the ground; for it is so ill-made that it cannot stand upright on its legs, but moves clumsily forward by dragging itself on its elbows. It seems, however, that when once in a tree it is a different creature altogether, and can scramble lightly from branch to branch. Moreover, if its claws cannot reasonably be reckoned as hands, they are at all events excellent hooks; and when it is springing about thus in the forest, suspended to the branches by its long arms, one might be tempted, while watching it from below, to decide in favor of M. de Blainville's opinion. I saw it originally myself in a cage.

As to the sloth's relationship to the armadillo, this rests upon a detail which bears directly upon our subject. The molars in both animals are cylindrical and smooth, this is a trifle, but what would you have? The animal had to be classed somehow; since naturalists have not had the wit to make detached companies, as they do in regiments of soldiers.

Order 11. *Amphibia* (*two-lived*).

We are going farther and farther away. Here are animals who are nearly half fishes (*ἀμφίς double*, and *βίος life*). The *Amphibia* have two lives: one in the water, which is their true life, and where they are in their element; the other upon land, where they can only crawl; for their paws, which are but half developed, are destined to perform the office of fins, and the hinder ones are extended flatly behind them, and act like a fish's tail. They are divided into two families, the seal and the walrus. The first feed on fish, and have the same internal organization as the *Carnivora*, as well as the same dental conformation. Some species have even exactly thirty-two teeth, as we have. The jaw of the walrus is the least regular, and the incisors are generally wanting, especially in the full-grown animal; for it appears they lose them very young, as you lost your milkteeth, only, unluckily for the walrus, his never grow again. On the other hand, he has two canines in his upper jaw, which, next to the elephant's tusks, are the largest we have yet met with. They are sometimes as much as two feet long, and incline downwards with a curve, like the two bars of a pick-axe. They would play the walrus the same trick that the incisors of rodents are apt to do when they have not work enough to wear them down; that is, stop up the entrance of its mouth, were it not that the lower jaw is contracted in front, in order to fit into the space between the two canines, which thus form a sort of passage in which it manœuvres freely. As you may suppose, the walrus cannot insert prey of any great size into this contracted passage; but that is no matter, as he lives partly on seaweeds, and partly—indeed principally—on shell-fish; his molars being specially adapted for breaking shells. They are short massive cylinders—the upper ones fitting into the lower as a pestle into a mortar.

After the walrus comes a strange animal which has been ranked among Cetaceans (we shall see why presently), but which it would be better not to separate from the Amphibians, since an Amphibian order has been made, for it crawls from time to time upon land: this is the Manatee, or Sea-cow. It comes still nearer a fish than the others. Its forelimbs are absolute fins, with mere vestiges of nails at their edges; it has no hind ones, and its body, which is quite cylindrical, ends in a fin tail in the shape of a shovel. The sea-cow feeds on plants and herbage, and lives at the mouths of great rivers, going up them occasionally to great distances, their banks serving it for pasture ground. In some respects it is half brother to the hippopotamus and the great grass eating *Pachydermata*, to whom it comes so near in internal organization, and above all in the structure of its molars, that M. de Blainville seriously proposed ranking it among the elephants, though as an *irregular elephant*, as you may suppose. But then Cuvier had even placed the seal among the *Carnivora*, by the side of the cat, whose whiskers it possessed, and of the dog, whom it resembled in the formation of its head. A naturalist's office is sometimes very perplexing, I assure you; and as we are touching on this subject, I cannot resist telling you that the sea-cow laid claim to, on so many sides, had by right a free admission to the celebrated order of *Primates*, although it looks exactly like a large barrel elongated at the two ends. It suckles its young at the breast like man and the monkey; and if Linnæus flinched from this rather too absurd parentage, old navigators were less scrupulous. Observing this creature in the distance, sporting on the waves, the upper part of its body quite out of the sea, the sailors, whose eye is not of the most refined, and who have no objections generally to the marvellous, imagined they saw a new species of human beings; and hence arose those stories of mermaids and sirens which have been told from the days of Homer downwards, and the traditions of which have not yet quite died out in seaport towns. To have been passed from man to the whale, touching the elephant on the road, is a long way to travel, especially when, after all, one is only a huge barrel of amphibious fat; and you may judge from this that it is not always an easy thing to classify animals.

ORDER 12. *Cetacea* (*whale-kind*).

Cetaceans are whales; and if I had been consulted on the matter, I should have joined this order and the last together, under whatever name was thought most appropriate. The passage from the seal to the whale through the walrus and the sea-cow is an easy and natural one, the two latter being obviously the connecting links; and in spite of certain diversities of food, they form in reality one family-party, as do the marsupials.

But it is too late in the day to talk of this, my dear child, and you and I cannot pretend to alter what is taught in the schools.

But you are astonished, are you not? to hear that the whale is not a fish: and no wonder. It is with it, however, as with the armadillo; it is a fish with a higher organisation inside. The interior of this enormous mass is a faithful reproduction, as a whole, of that of the shrew-mouse; and when we come to talk of fishes you will have some faint idea of the prodigious distance which this places betwen the whale and his countrymen of the ocean.

As far as we are concerned, the chief difference is in their way of breathing. The cetaceans breathe like ourselves, and are obliged to come to the surface of the water to take air; while fishes have a special apparatus, which I will explain to you presently, which enables them to breathe in the water. This is a disadvantage to the cetacean in his fish life; nevertheless, of all the mammals (as may easily be imagined) he is the one who can remain longest under the water. With us, for instance, the best divers one ever heard of, those who go to the bottom of the sea after the pearl-oyster, can scarcely stay below longer than two minutes; and even during that short time the veins of the head become so overcharged with the blood, which cannot return to the lungs owing to its forced inactivity, that when the diver comes back to the surface it is by no means unusual to see him streaming with blood from both nose and ears. The cetaceans remain under water for half an hour at a time without seeming to suffer in the least; and Breschet, a clever French naturalist, has given a very satisfactory explanation of this wonderful faculty. In dissecting a cetacean he discovered all along the vertebral column an exten sive network of large veins, which are not found in other mammals, and which seemed designed to serve as a refuge-place for the blood during the time the animal remains submerged. According to him, this network would act as a reservoir, to which any overplus in the head or important organs would flow through vessels communicating therewith, and which might swell out as it pleased, without any risk to the inert bed of fat against which it lies. From thence the blood rushes to the lungs, as soon as the animal's return to the air enables them to play as usual. It must be admitted, at the same time, that all this involves the necessity of a much less active life than that of land mammals, that is to say, a consumption of oxygen much smaller in proportion than theirs; for were you to be furnished down your back with the finest network reservoir in the world for venous blood, it would still not enable you to remain half an hour without breathing.

There is nothing remarkable in the digestive apparatus of the cetaceans except about the mouth, which is, as you know, the essentially variable point among animals. To begin with, the cetacean tongue has the most original appearance possible. Indeed, it is not a tongue, but a large carpet, spread over the floor of the animal's mouth, and bears not the faintest trace of resemblance to that nimble delicate porter, who does you such good service. Imagine a thick soft lump absolutely crammed with fat, and completely immovable, because it is glued down along its whole length to the bottom of the mouth, and you will have a good idea of this strange tongue, which in the whale, the largest of the cetaceans, attains to the length of twenty-five feet and the width of twelve, and of itself alone furnishes the whale-fishers with from five to six tons of oil. This is a great deal farther from us than even the long string which serves as a tongue to the ant-eater; and you feel at once that we are getting among strangers.

With respect to teeth, I have now a melancholy piece of news to tell you. We have done with them; we have seen the last of incisors, canines, and molars, henceforth you will hear no more about those valuable instruments. The teeth of the cetaceans, with whom this painful falling-off begins, are no more teeth than his tongue is a tongue. They are like so many nails set in a row in the jaw, and can only be of use in retaining prey, not in grinding it; so that of the many processes your bit of bread has to go through before it becomes a part of yourself, there is one which is dispensed with here altogether, namely, mastication. Cetaceans swallow their food without chewing it.

Besides, they have not got a whole set even of these unmasticating teeth. Dolphins and porpoises, those faithful companions of the sailor, around whose vessel they come playing and tumbling in the seas of all countries, are the only ones who have them in both jaws. And these are the small fry of the order; they do not usually exceed six or ten feet in length.

The Cachalot, or Spermaceti Whale, an enormous cetacean, which rivals the true whale in size, and whose head alone forms nearly the half of its body, has teeth in the lower jaw only. This lower jaw, whose two sides are joined together for half their length (a new deviation, very unlike anything we have found before), is so little proportioned to the gigantic head which contains it, that it is almost lost to sight, and seems like a small plank slipped under a great square block.

Such as it is, however, it possesses many very respectable teeth, of which some weigh as much as two pounds;

and with these the cachalot, whose ferocity is tremendous, tears in pieces everything that comes near it, sometimes even the boats of the fishermen who risk their lives in the dangerous pursuit of capturing them. By a singular arrangement, of which this is the only known instance, there is, opposite each of the cachalot's teeth, a corresponding cavity in the upper jaw, into which they fit closely, turning the monster's muzzle into the most formidable pair of pincers to be found in the animal kingdom. Another curiosity in the order is the tooth of the Narwhal, a modest cetacean, who is not much more than twenty feet long!

I speak of *the tooth*, because the creature has commonly but one; a cylindrical-pointed tooth, spirally furrowed, whose length varies from six to ten feet, and which comes straight out from the extreme front of the upper jaw, like a soldier's pike. There are two sockets at this extremity of the jaw, each furnished with a tooth-germ; but as a general rule the germ on the left side is the only one which develops, the other lying asleep in its socket, where it is choked up and never appears. Behind this long pike, which, like the tusk of the elephant, attracts to itself all the ivory in the body, lies a completely unfurnished mouth; so that the owner of this magnificent weapon, invaluable as a war-tool, but quite inapplicable to the purpose of supporting life, is obliged to feed on small fishes and *mollusks*. We have not yet spoken about these latter, but if you have ever seen slugs and snails you will know what a *mollusk* is.

The same wretched food falls to the lot of the whale also, that giant of the ocean, whose open mouth forms an aperture twenty feet in extent. Geoffroy St. Hilaire, in his indefatigable endeavors to trace out points of resemblance connecting together animals the most unlike in outward appearance, discovered, along the lower jaw of a young whale, certain traces of teeth, indicating a last effort on the part of nature to carry out her usual plan in furnishing the jaws of mammals; but, like the right-hand tooth of the narwhal, these vain attempts soon disappear, overgrown and lost in the tissue of the bone, so that the whale offers us a true type of an *edentate*, classable with the ant-eater, if one dared, and some people have dared, which by this time will not surprise you. A classifying professor is utterly merciless, whether he gets hold of the poor beasts by the mouth or by the paw: they may protest with all the rest of their body against the peg on which they are hung; so much the worse for them! If one were to listen to what they have all got to say, it would be impossible to classify even one.

To return to the whale. As a compensation for the teeth which she found herself unable to give him, nature has manufactured on the two sides of his upper jaw the most extraordinary apparatus without exception to be found in the mammal mouth. You know what is called the *whalebone* used in stay-making, &c. The name is quite correct; for those little flexible black strips, which support the figure so nicely, began life in wandering over the polar or Australasian seas, fastened to the palate of some monstrous whale.

On the two sides of the upper jaw the membrane which covers the palate sends out rows of broad, thin, horny plates, which are from eight to ten feet long (they have sometimes been seen twenty-five feet) in the centre of each side, but which decrease gradually towards the extremities. These are plates of whalebone (sometimes called whale's whiskers), and the industry of man has turned them to a thousand different uses; and you will open your eyes in astonishment when I tell you that 800 or 900 of them have been sometimes counted on each side of one mouth. Think of the number of stays that could be furnished from the whalebone plates of one whale! It is true, they were not exactly designed for this purpose originally. At the tips and on the edges of these plates, the elastic fibres of which they are composed unravel and peel off, and hang down from the lip like tufts of horsehair. The Arctic seas, which the whale inhabits, are, like other seas, full of innumerable troops of various little sea-animals, and it is these which are destined to the honor of nourishing this gigantic mass of flesh. When the colossus wishes to take a meal, he stretches his mouth to its utmost width, and the salt water rushing in as into a gulf, carries with it the imprudent little fry, who disappear then and there for ever, being retained by the fringe-like sieve of the whalebone. But as, in this way of eating, the stomach of the whale, however large, would be terribly overgorged with water, he is furnished with another apparatus for preventing the inconvenience. All the superfluous water is rejected by the *pharynx*, and springs up in spouts of fifteen or twenty feet high, through the nostrils, *i.e.* the nasal openings, sometimes called "vents," sometimes "blow-holes," which are pierced exactly at the top of the head. This is a peculiarity common to all cetaceans, who have thence received the name of "blowers," alluding to the powerful blast which is necessary to send those majestic columns of water into the air; but it takes a much milder form with the lesser cetaceans, such as dolphins and porpoises. There is but a slight jet with them: the water escapes comparatively quite quietly from the nostril-vents, trickling away down the animal's sides.

I hope you consider that I have told you something new this time, my dear child, and that our machine is beginning to change its appearance very materially. I told you before that we had reached the outskirts of the mammal kingdom. When we got to the armadillo we were within a stone's throw of the reptiles, and here, one step more would take us to the fishes. But we must first consider the birds, who are a very superior set of animals to either of the latter; and we have accordingly an order of mammals (Monotremes) which, as you will now find, opens the road on that side also.

There are but two sorts, and both of them are natives of Australia, which is, as you may have heard, the land of the wonderful in natural history, and their existence was unknown to the learned men of Europe till within the last sixty years. The most extraordinary of the two is the *Ornithorhynchus*, or, to translate the hard Greek word into English, the *Duck-bill.* Its mouth is a true duck's bill, a downright horny beak, and its short paws sprawling sideways with a membrane joining the toes together below, and coming a good deal beyond them in front, seem intermediate between the flippers of the seal and the webbed feet of a water-bird. The first naturalist who had anything to do with the ornithorhynchus, Blumenbach the German, who gave it its pretty name, did not think it was able to suckle its young, so much did it differ from mammals in some respects, though looking so like them on the whole. And presently a report arose in the learned world that the new animal which had been classed at all risks among mammals (it having the close fur and almost the body of the otter), a report arose, I say, that this ornithorhynchus of Blumenbach laid eggs like a real duck. The uproar in the Academies was tremendous. As early as 1829, indeed, a learned Englishman, Sir Everard Home had sent over to France an authenticated drawing, as he said, of an ornithorhynchian egg, to the delight of the hunters after analogies among animal races; while Cuvier looked sadly askance at the intruder, whose arrival threw his animal outlines into confusion, there being no place in them for such a beast. Happily for the poor animal, he has ended by almost settling the matter for himself. The ornithorhynchian egg has never turned up. But in the animal's nest have been found baby ornithorhynchuses, newly born, under two inches long (the full-grown animal being more than a foot and a half), and not a trace of eggshells near. Further investigations showed that the mother ornithorhynchus nursed her young with milk, for curdled milk was found in their stomachs; so the Australian phenomenon has been restored triumphantly to the Mammalian order, whence Geoffroy St. Hilaire had excluded both it and its companion, the *echidna*, a sort of hedgehog, provided like the ornithorhynchus with a bird-like bill, only more of the canary-bird sort; and like it, also, approximating to the bird tribe by other details which do not belong to our subject. And so the matter stands at present; and all we venture to say is that classification had a very lucky escape.

And now, my dear child, that I have made you acquainted in detail with your nearest neighbors, the last of whom, nevertheless, are strangely unlike you outside, however they may resemble you within, I shall take the liberty of going more quickly over the ground, and shall point out in the mass only the more important changes which lead from one class of animals to another. I should be found fault with if I tried to make you too learned, and you yourself might be tempted to tell me, to my sorrow, that you had heard about enough.

LETTER XXXIV.

Aves. (*Birds.*)

Tell me, my dear child, when you have seen birds taking their flight into the air, and going boldly to their object, without a thought of all the barriers, ditches, rivers, and mountains, which hinder man at every step in his travels, did it never strike you to wish for their wings, and imagine how you would fly off if you had them? If you ever dreamt this dream, do not apologise for it; it is one as old as the world. 'Oh that I had wings like a dove!' cried the Prophet, nearly 3,000 years ago; and the dialogue of the swallow and the prisoner, so often sung by poets, has been repeated in prose behind all the prison-bars on the globe since prisons were first invented.

Now you will not think it kind on my part, but I must undeceive you about this fancy, as you will be undeceived some day about many others. The wings of a dove or swallow would be of no use to you if you had them, any more than the formidable swords of the middle ages would be to our modern gentlemen, were any one to put such into their hands. We are not adapted for them, nor they for us.

You saw, some time ago, what an amount of muscular exertion was required for running—what a violent flow of blood, what hurried play of the lungs. Now in flying it is still worse; for the earth, at any rate, holds us up quite naturally, whereas the air will not hold up the bird unless it is beaten vigorously and unremittingly by an untiring wing. If we men, constructed as we are, had to do such work, we should be out of breath at once; the heart would cry out immediately for quarter, and the diaphragm turn red with anger. And only just imagine in what a critical position a poor wretch launched into the air on the wings of a swallow would find himself when, at the end of five minutes, his servants should refuse point-blank to go on working at a height of 500 feet above the ground!

But a bird has not these internal rebellions to fear. In the first place, it has no diaphragm; so here is another friend to whom we must say good-bye. We shall not meet with him again anywhere. The journey we are taking together, my dear, is somewhat like the journey of life. One sets off, surrounded by friends and acquaintances, but whoever travels on to the end is apt to find himself alone at last; this is what is happening to the digestive tube, which we shall see losing all its accessories, one by one, as we gradually advance in our study. Even now here is one essential fundamental difference in the internal machinery. The body has only one compartment instead of two; and the lungs, masters of the whole space, extend freely to its utmost depths. When a fowl is cut up at table, look along the body, and you will find lodged in the cavity of the ribs, a long, blackish, and spongy mass: this is the lungs. There is not, therefore, the same danger of a bird's getting out of breath as with us; that delicate board which is found in our bellows is wanting in his. His is set in action solely by the to-and-fro movement of the ribs, which is produced by muscular exertions, which are greatly increased during the action of the wings. From which it follows, that the rapidity of flight itself regulates the arrival of air, and consequently the expenditure of strength, or, if you like better, the activity of the fire, since the energy of the muscles depends, as we have seen, upon the quantity of oxygen that feeds the internal stove.

This is not all. These elongated lungs are still not sufficient to furnish the blood with all the oxygen demanded by this excessive labor of flight. They are pierced with holes, through which issue pipes which carry the air all over the body. You know what is said of spendthrifts?—that they burn the candle at both ends. It is so with the blood of birds. That fillip which in our case it receives in the lungs, and which sends it back full of vigor into the arteries, is repeated in the bird at the other end of the arteries as well. The capillaries, those delicate vessels at the end of the arteries, plunge from all sides into little reservoirs of air—lungs, therefore—where the blood renews its provision of oxygen, and relights its half-extinguished fire, so that it sends the combustion afresh into the muscles on its return back to the heart, and sets them going a second time.

The natural consequence of this prodigality of combustion is, that there must be, in proportion, much more oxygen in birds than in us; and that of all animals a bird is the one most quickly poisoned by his own carbonic acid when the air is not renewed around him. Therefore, let me beg you never to think of putting a poor little bird under a wine-glass, as a child of my acquaintance once did, that she might examine her little friend more closely. In the twinkling of an eye he would consume all the oxygen inside his prison, and you would soon see him fall upon his side and die.

On the other hand, the temperature of these flying machines, which consume so much oxygen, is very much higher than ours. It rises to 41°, 42° (centigrade), and sometimes to 44°, 7° higher than with us. If ever you have taken hold of a little bird, you will have remarked how warm it makes your hand: this is quite natural, since there is always a double fire going on within him, to meet the extraordinary expenditure of strength that is required of him whenever he takes wing. Besides, do but look at the poor little creature when you have imprisoned it in a cage! How it goes up! How it comes down! How it hops from one perch to another, with a quick sudden movement, like that of a spring when it unbends. There is no apparent cause for this state of continual agitation; and yet there is a cause, and only too serious a one. Its fire is not slackened because you have put it into a cage, and its muscles, lashed furiously on by the double-oxygenized blood, drive it hap-hazard into a thousand movements, in which it expends, as best it can, a superabundance of power, which no longer finds natural employment. Little children, who are the real singing-birds of our homes, and whose blood also drives much more energetically along than ours—little children, I say—often fare no better than caged birds in those larger cages we call schools; and schoolmasters and governesses would scold rather less if they thought rather more about this. It is right, I do not deny it, that the rebellious young rogues should be taught in good time not to abandon themselves, like wild birds, to the mere animal impulses of the blood; but, in dealing with them, one must also make allowances, as they say, for the fire within, and know how to open the cage now and then. It is not for you, however, that I say this, young lady: you are no longer a little child; but it may happen that you may have some to take care of some day. Believe me, then, you must not expect too much wisdom from them, and you must allow them to change their perch every now and then. It is a law of our Almighty Father that little children, and little birds, should not stay too long in one place.

The mechanism of the circulation is here the same as with us, and does not offer any important peculiarity. Only the left ventricle of the heart has walls of extreme thickness, which enable it to launch the blood into the members with greater vigor and rapidity; and the blood itself, although it is composed of precisely the same materials as that of the mammals, differs from it nevertheless as regards the globules. In the first place, they are more numerous; secondly, they are larger; and finally, instead of being round like a plate, they are drawn out ovally, and are almost shaped like those long dishes on which fish is usually served. I shall not attempt to give you the reason of their size and form. This is hidden from us in the same mystery which envelopes all the microscopic population of the blood; but is it not a curious thing, this strange persistency of form in the globules of all animals of one class? In all birds they are oval; in all mammals they are round. In all? Nay, I am wrong. As if the better to hide from us the key to this riddle, nature has amused herself by making an exception. Camels and llamas, I forgot to tell you, have also globules in the form of long dishes, like the hen and the chaffinch. Find out why, if you can. As to the reason of the number, it is a very simple one. Since the energy of the blood resides in the globules, it follows that the most energetic blood will contain the largest amount of globules. Looking at you, for instance, little monkey, running and jumping about the garden, I would lay a wager, without counting first, that there are, in one drop of your blood, some millions more globules than in one of mine.

Let us now go on to the digestion, with which, properly, we ought to have begun; but I preferred pointing out to you, first, the particular character which is the chief mark of distinction in the organization of the bird

'When hens grow teeth,' says a shrewd proverb, meaning of course, *never*. Birds have no teeth, and in this respect there is no variety among them. All, from the first to the last, have uniformly the same tool to eat with—the bill, that is—which is, in all cases, composed of the same elements, two jawbones elongated to a point, and clothed in a horny armour, which makes their edges sharp and cutting. At the same time were we to review the birds in detail, as we have done the mammals, you would see that there are almost more modifications to be observed in this one single instrument than in our thirty-two teeth. All birds have a beak, but each has his own, organized expressly with reference to the kind of food needed by its owner. The eagle's beak, which mangles living prey, is pointed, bent, and hard as steel; the bill of the duck, which laps up water from ponds and puddles, in order to get worms and half-decomposed refuse out of it, is soft, and flattened like a shovel. The woodpecker's, which has to pierce the trunks of trees, is like a pickaxe; that of the humming-bird, which has to suck up the juice of flowers from the bottom of their corollas, is slender as a needle. The swallow feeds on flies, which it snaps up on the wing, and has a soft bill, which opens like a little oven. The stork picks up reptiles in the mud of the marshes; its beak is straight-pointed, cutting as a knife, and resembles a long pair of pincers. The sparrow feeds especially on hard grains, difficult to break; accordingly its beak is stumpy, short, and thick, and is arched on the upper side for still further solidity. But I should never end if I began to enumerate all the thousand varieties in the bills of birds. Each variety, too, corresponds with some peculiar sort of life, and consequently with a general conformation (easily ascertained) of the animal in which it appears. Give a naturalist the bill of a bird —only its bill remember—and he will tell you half its history without fear of being mistaken.

On the other hand, we must not deceive ourselves as to the real value of this complaisant bill. Let it transform itself as it pleases into all manner of forms for the better fulfilment of its task, it makes, at the best, but a very poor instrument for mastication; nay, to say the truth, it breaks, cuts, and tears, but it never masticates at all. Thus the bird's mouthful is far from undergoing as perfect a preparation as ours does. It is no sooner taken in than it is swallowed, and the salivary glands, which are still to be found under the tongue, seem only to be there as a matter of form; what little saliva they produce is thick and sticky, and has none of the qualities necessary for making that liquid paste which our tongue sweeps up from every corner of the mouth. Besides, it must be owned that a bird's tongue would be a very awkward implement in such a task. Open a hen's bill and you will see therein a very inferior sort of porter. It is merely a dry hard lance, as it were, armed with prickles at the point, as ill-qualified for tasting as for sweeping. So the hen does not waste her time in finding out the flavor of what is thrown to her. She picks up and swallows over and over again, without appearing to experience any other pleasure than that of satisfying her appetite. Birds of prey, it is true, have rather more convenient tongues, capable, moreover, of tasting up to a certain point; and the parrot, who is a complete epicure, and chews his food philosophically, has a charming little black one, thick, fleshy, and susceptible—a true porter, in fact—who enables Polly thoroughly to enjoy her breakfast. But certain birds who live on insects surpass even the hen in the dryness and hardness of their tongues. That of the woodpecker, especially, is a model of the kind, and deserves a few words more than the others. Picture to yourselves a long pin, terminated by an iron point with barbs like those of fish-hooks. An ingenious mechanism enables the bird to dart it out with the rapidity of lightning, far beyond his bill, upon the insects to which he gives chase. The point pierces them, and the hooks retain them, without any need of assistance from the bill. I have just told you that this bill pierces the bark of trees; but it only plays the part of gamekeepers on grand sporting occasions, who beat the bushes to make the game rise. The woodpecker's bill routs up the insects by destroying their shelter; but the real sportsman is the tongue. Good-bye to any notion of a cosy little chat in such a porter's lodge as that! What could a harpoon have to say for itself?

Do not, however, let this miserable entrance-hall alarm you, at the same time, for the fate of the mouthful thus presented half-dressed to the œsophagus. You will find it only so much the better treated within. In the first place, the œsophagus, when half-way down to the stomach, swells out suddenly and forms a pocket, which is generally particularly well developed in birds who feed on grain; this is called the *crop* in English, in French *jabot;* whence comes the application of that word to those full shirt-frills which have sometimes been the fashion. It is the pigeon's *crop* that gives him the rounded chest over which he bridles so prettily. The crop is a receptacle where the food makes a halt: it is something between the pouch of the monkey and the paunch of the ox; a preparatory stomach, which does not, it is true, send back the grain to the bill, for the bill could do it no good, but in which that grain lies until there is room for it further on.

From thence it resumes its journey; but, before reaching the true stomach, it passes through a second enlargement of the œsophagus, whose walls are pitted with numberless little cavities, from which pour over it the juices destined to supply the place of the saliva that was wanting above.

It reaches its destination at last, but still hard, and generally whole. No matter, however. The stomach which receives it, and which is called the gizzard, is quite a different sort of thing from a useless membrane, thin and delicate like ours. It is a thick muscle of enormous power, lined inside with a kind of horny skin, so tough that nothing can break through it. You may form some idea of the prodigious strength of this organ, when I tell you that turkey-fowls have been made to swallow hollow balls of glass, so thick as not to break when dropped to the ground, and that at the end of a few days they have been found reduced almost to powder in the uninjured stomach. No fear of indigestion with such an apparatus as that. Though the grain may not have been masticated in the bill, what does it signify? There is a power here, as you see, quite equal to carrying the whole work through. Thanks, indeed, to the invaluable horn which lines it, fowls which have no teeth of their own can safely present themselves with as many and as hard ones as they please. They swallow small pebbles, which rub against the grain, during the contractions of the gizzard, and act just as effectually as if they were fixed in the jawbone. Well, this terrible gizzard performs its crushing work with such energy, that not only the grain but the pebbles themselves are ground down there, and end by being pounded into fine sand. When you rear fowls, do not forget, if you keep them shut up, to put within their reach a store of small pebbles, so that they may have teeth to run to in time of need.

You remember the *pylorus*—the porter down below, who keeps the door of egress from our stomach? He is as badly provided for here as his fellow-workmen up above; worse in fact. It is a gaping hole, and we cannot expect a very strict supervision from it. Birds who feed on fruits profit by this fact to carry vegetables from one country to another. With such an easy opening, seeds have a good many chances of passing from the stomach unaltered; and then they drop from the clouds, as is supposed, hap-hazard, and germinate afterwards, when circumstances prove favorable, to grow up before the astonished eyes of the natives into plants of which they have never even heard. The French Acclimatization Society, which I spoke of lately, and which, though so modern, has correspondents all over the globe, is at this moment laboring to effect an exchange between all countries of the natural productions of their soil. But here you see that nature had thought of this before, and established her acclimatization society long ago.

To complete the internal work of digestion, so feebly begun in the bill, an extremely large liver pours torrents of bile into the duodenum, and the manufacture of chyle proceeds with that wild rapidity which characterizes all the living actions of birds. But speaking of this liver, I think I ought to give you an account of a celebrated dish, considered a great dainty by epicures, called *pâtés de foies gras—fat liver patties*, to translate it into its meaning. Very likely you will not care to eat them after hearing my story; but that will be no great loss to you, for it is a very indigestible sort of food, and not at all good for children.

You remember my telling you about Englishmen going to India and coming back with a liver-complaint, from having eaten and drunk more than the climate allowed? By an imitation of this process, human ingenuity—occasionally so cruel—has created the *pâtés de foies gras*, the glory of Strasburg. I have been in the country, and can tell you how it is managed. They shut a goose up in a square box, where there is just room for his body. They open his bill at feeding-time, and cram down with the finger as much food as can be got in. This is throttling rather than feeding it. The poor beast, who can use no resistance, since it cannot move, and who is kept in the dark to prevent excitement; the poor beast is quite unable to burn all the mass of combustibles with which the blood soon finds itself loaded. This carries them to the liver to be turned into bile; but the liver is not equal to the work, becomes loaded in its turn by unemployed materials, and grows and grows, till at last, having filled up all the space around it, it stops the play of the heart and lungs. When the animal is nearly suffocated they kill it; and this is how we come to have *pâtés de foies gras* to eat! If they give us a fit of indigestion afterwards, it is a vengeance we richly deserve. At Toulouse, where the same trade is carried on on a large scale, they used formerly to go even beyond this. They fastened the goose by the feet before the fire-place, after having put out its eyes. The imitation of the Englishman's proceeding was still more perfect here, for the fire acted the part of the Indian sun to perfection. I do not know that part of the country well enough to tell you whether they have quite given up this piece of wicked ingenuity; all I can say is, I devoutly hope so.

The intestine of birds is much shorter than that of mammals. Here everything is done at full gallop, and the chyle has not to go far before it is absorbed. I have before me a book, in which I am told that the wagtails eaten in France can be fattened in twenty-four hours, if you only know how to set about it, and these birds are not rare; they belong to the same family as the redbreasts, the tomtits, and the nightingale. Thrushes and wheatears (ortolans) require, for the same purpose, four or five days in the same country, left to themselves to roam about, when the vine keeps open table for them.

This incredible quickness, not only in digesting, but, what is much more, in transforming food into fresh living material (*assimilating* it, as it is called), has often a fatal result for the bird. He is prohibited from fasting; his life is a fire of straw, which must be replenished unceasingly, or it will die out in the twinkling of an eye. Our own little birds—children—eat oftener than grown-up people, and if by any accident they are kept waiting awhile, they soon cry out with hunger. You know this, do you not? Well, then, if any one should give you a bird to keep in a cage, remember that you have undertaken a great responsibility, and that it will not do to be careless with him. To neglect feeding him for one day is to run the risk of finding him starved to death next morning. With this warning, I will conclude my chapter on birds. I hope I have not spoken in vain in behalf of those poor little captive songsters, whose fragile lives are at the mercy of their young masters and mistresses.

LETTER XXXV.

REPTILIA. (*Reptiles.*)

PASSING from birds to reptiles is like falling from a torrent into still water. Life drags on as sluggishly with the second as it dashes furiously forward with the first.

I spoke to you just now about a fire of straw: now we have a fire such as Frenchwomen make in their *chaufferettes*, or foot-stoves. A handful of charcoal-dust, and a few live embers between two layers of ashes, is enough for the whole day; which is economical, is it not? but then it throws out only just warmth enough to keep one's feet comfortable. And so it is with reptiles. They live at very small expense. If you feed them once a month they will not complain, for so slow a fire does not often need replenishing with combustibles. It is even said that the experiment has been carried so far with tortoises that they have been made to fast for more than a year, and still the charcoal fire kept up its languid pace. Of course, on the other hand, there is not nearly so much oxygen consumed at once upon such a diet as this. Where a bird would perish twenty times over in five minutes for want of oxygen, a lizard can remain whole hours with impunity. Moreover, the animal heat of reptiles is in proportion to their expenditure of it. Graceful as is the snake (that living jewel so often copied by bracelet-makers), you feel on touching it an instinctive horror, caused by the thrill of cold it produces. All the animals we have considered hitherto have warm blood, and bear within themselves the source of their heat, which is pretty nearly always the same. But reptiles are cold-blooded, and heat comes to them chiefly from without.

If, at the end of a cold winter, we go to some favorable corner to catch the first rays of spring sunshine, we feel ourselves almost re-born, as it were, as if a new life had come into us with the sunbeams. Look at the little lizard you see frisking on the white stones of the wall; upon him decidedly the sun is darting actual life from its rays. While the cold lasted he staid squatting in his hiding-place—not asleep, but annihilated—congealed, so to speak, like water caught by the frost; no longer digesting, and hardly breathing, he had ceased to live in reality: and it is no imaginary regeneration which the return of warmth brings to him. Like those helpless people who have not the power to carve out their own destinies, reptiles have within them only an insufficient source of animation; their life is at the mercy of the sun, and is high or low, according as that rises or sets in the heavens. At Martinique, where at noonday it darts its devouring rays perpendicularly upon the cane-fields, and every one flies into the shade to escape its scorching heat, the rattlesnake traverses the country, monarch of all he surveys; he strikes rapidly with a vigorous tail upon the calcined ground; and woe then to any one who receives his bite! All the fire of the atmosphere has passed into his frame. Now go to the Zoological Gardens, and see him there: he crawls languidly under the coverings that shelter him; if by chance he bites any one, it is with an idle tooth that no longer knows how to kill; his life was left behind with the sun of the tropics, and it is little more than a corpse that you are looking at.

And so among ourselves, my dear child: we meet with people whose whole power comes from without, who are brilliant and haughty in the sunshine of good fortune, but crest-fallen, cowardly, and cringing in the cold days of adversity. Nevertheless, they are constituted originally like other people: they are neither greater fools as a general rule, nor less gifted than their neighbors; where they fail is in the heart, but that is enough to spoil everything. And so with reptiles: the heart is their weak point also. Like us, they have lungs into which the air pours without any difficulty, and a heart to send the blood to them; so it seems at first sight as if there could be nothing to prevent their resisting the changes of external temperature just as well as ourselves. There is only one small trifle wanting, and that is a partition in the middle of the heart; but this one defect is enough to disorder the whole machinery.

You know that, with us, the heart is divided into two compartments: the right ventricle, which receives the venous blood from the organs and sends it to the lungs; the left ventricle, which receives it (now become arterial) from the lungs and returns it to the organs. Hence the double system of veins and arteries, the one going from the heart to the lungs, the other from the heart to the organs. All this is found the same in reptiles: except that the partition, which separates our two ventricles from each other, does not exist in them; and the heart has only one common room, in which, therefore, arterial and venous blood become mixed together. It follows from this that, at each contraction of the heart, it is a mixture of arterial and venous blood which is sent in the two opposite directions at the same time, and that the organs receive some which has been used before, while the lungs have some returned to them which has been regenerated already. Now, on the one hand, this mixed blood can only keep up an imperfect combustion in the body (like the live embers between two layers of ashes that we spoke of lately), and, on the other hand, the air in the lungs can only act upon a part of the blood it meets with there, the rest having already undergone the regenerating process. And this accounts for both the feeble animal heat and the small consumption of oxygen in reptiles.

Added to which the lungs of a reptile are coarsely constructed, and composed of cells enormous in comparison with ours, so that the blood does not find nearly as many little chambers to rush into for a taste of air as with us. Moreover, you must understand that there is no such thing as a diaphragm here: the lungs float loosely in the form of elongated bags in the one only cavity of the body, and the slight movement of the ribs does not allow them to dilate sufficiently to take in much air at a time.

All these things, taken together, make the reptile a very poor stove, and render him incapable of any prolonged exertion. The serpent darts like an arrow upon his prey; but he could not pursue it for half a mile without stopping, not even over the burning soil of the equator. The lizard is very nimble, is it not? and the quickness of its movements rather reminds one of the agility of a bird. But watch it, and you will see it only moves in jerks, and keeps stopping every minute; it cannot escape you if there is no hole near into which it can disappear. In France there is a large green lizard that runs among the vine trees. If you pursue him he is off like lightning for a second; then he stops suddenly short. You return to the charge, and he starts afresh, but only to stop again. At the fourth or fifth attack he is quite out of breath ; you poke him with the stick with which you have been hunting him, but in vain ; there he lies motionless, in spite of his alarm. A few steps have brought him to the end of his powers, like a man whose heart is diseased and who cannot go far. This, however, is a peculiarity common to all reptiles. Each of the three orders of which this third class of Vertebrata is composed has its own particular history besides. You must excuse my mentioning the barbarous names that have been given them, and allow me to call them *tortoises*, *lizards*, and *serpents*, like other people. The hard names mean no more than these ; but they are Greek, which is always more imposing.

The slowness of the tortoise has passed into a proverb, which is not to be wondered at ; for they cannot inhale the air, because their ribs (which are a reptile's only resource for breathing) are condemned to absolute immobility. The *carapace*, or shell, which the tortoise carries on his back, and under which it retreats upon the least alarm, as under a shield, is really formed of its ribs, each of which has widened itself so as to join on to its neighbor, like the boards of an inlaid floor, which run one into another. Of course there is no question of moving up and down with such ribs, and the poor bellows cannot work at all. How does the tortoise get out of this difficulty then, you will ask ? I answer, it swallows air, as we should swallow a glass of water. You see its mouth open and then shut again, thereby taking in an actual mouthful of air, which the sides of the mouth, by contracting themselves, send straight to the lungs. These, which are very large, get filled in this way by degrees, and, when they are quite inflated, they expel the overplus by collapsing, like an over-stretched spring. You may imagine that this does not produce a very active respiration, and that a tortoise would be puzzled to run at even a moderate trot. To be sure, when he has once filled his great lungs with air, he has enough for a long time. Most tortoises are aquatic, and, as divers, leave the cetaceans far behind. Méry, an obscure French naturalist of the days of the Empire, pretended that he had kept in his house, *for a month*, some tortoises, whose breathing he had completely stopped. Only imagine from this how far their life must be below ours, although it is the result of similar actions, performed by organs which after all are copies (imperfect ones, it is true) of our own.

Some tortoises feed on vegetable substances, and some upon fish or small soft-bodied animals. Like birds, they mash their food with difficulty, by means of a real bill. Their jawbones are generally arched forward toward the front, and are furnished with sharp horny plates, in which a fairly-marked denticulation or notching may sometimes be traced, as in the bills of birds of prey. Indeed there is one, the *caretta*, whose hooked and notched beak so completely recalls the warlike bill of a hawk, that it is usually known by the name of the "Hawk's-bill Turtle." You ought to know about this tortoise, for it is the one which furnishes tortoise-shell, that nice material which is so smooth to the touch, so pretty to look at, and so very fragile, that it seems only fit for the use of ladies' hands. I could hardly speak of tortoises without saying something of this one, out of whose back was carved the handle of your own pretty little penknife.

Behind this bill of the hawk's-bill there is a tongue, but of the character of a whale's tongue, and it is fastened underneath to the bottom of the mouth. At the base of it there is a sort of fleshy pad or cushion, which serves instead of a soft palate, that being another detail which is about to disappear from our history. We are now really entering upon the simplification of the digestive tube, which will, I forewarn you, end by being nothing more than a perfectly straight pipe, without any appendages whatever. In tortoises the intestine is still tolerably long, and is doubled up backwards and forwards many times in the abdomen ; but it is already beginning to lose that variety of form which its different parts assumed in the higher animals. The large intestine can no longer be clearly distinguished from the smaller one, nor this from the stomach, which itself seems to be a continuation of the œsophagus, without any very distinct boundary line between them. The porter, who with us keeps the door of the stomach, does his duty here so badly, that there are certain kinds of tortoises whose œsophagus is covered with spines, the points inclined backward, to prevent the food from rising up into the mouth whilst the œsophagus is driving it down by its contractions.

In the gray lizards of our walls we find teeth again, but very different from any that we have hitherto seen. In the first place, they are not content with their usual place on the edge of the jaws, but encroach upon the surface of the palate, where they stretch out in close lines. Besides, they are even still less like teeth than the great nails in the jaws of the cetaceans. They are little ivory prongs, with the points turned inwards, analogous to the thorns of the œsophagus in the tortoise, and serve the lizard solely to retain and bruise his prey. He lives on insects, especially flies, which he seizes on the wing with the greatest skill, hastily catching and engulphing them in his open jaw ; they pierce themselves on the little prongs, and are swallowed promiscuously. The tongue of the lizard has also a curious peculiarity, which is shared by that of the serpent: it is divided at the end into two threads, which dart in and out of its mouth, and by means of which it laps, like a dog, the few drops of water it requires to satisfy its thirst. I have seen lizards which had been tamed by children greedily sucking up the saliva from their lips by drawing across them those little forked tongues of theirs, which, after all, are very soft, and perfectly inoffensive.

The tongue of the chameleon, another species of lizard, is still more curious. You must know that the chameleon is a lumbering lazy animal, who feeds on flies and other swift insects, and who would, therefore, be constantly liable to go without his dinner but that his tongue serves him for a hunting weapon, like those of the woodpecker and the ant-eater. When at rest, it is an oval spongy mass, lying comfortably in the mouth, with nothing formidable in its appearance; but let the prey come frisking round the chameleon, as if despising so helpless an enemy, and this great soft tongue is transformed into an active dart. It shoots forth like an arrow, and will sometimes seize the rash intruder at half a foot's distance, transferring it with equal rapidity to the motionless mouth. The blow is so soon struck, that it is very difficult to see how it all happens. Some say that the chameleon curves the tip of his tongue by a sudden effort, and then catches his flies with it, just as you would catch them with your hand. Others maintain (and this is the general opinion) that the tongue of the chameleon is terminated by a sort of sticky cushion, on which the flies are caught, like birds with birdlime. This singular dart is always out-jerked with such force that, if it strikes against a glass (the experiment has been tried with chameleons in captivity), it makes a sound as loud as that of a pea from a pea-shooter ; so you may judge if it is not strong enough to stun a fly. Besides this, too, the chameleon (who is by-the-by, a hideous little beast) has given endless trouble to naturalists on another and very different point. It is he who is so celebrated for his faculty of changing color when any emotion agitates him ; and ever since the days of Aristotle, who lived more than two thousand years ago, people have been trying to explain this, without any one being able to flatter himself that he has found out the exact answer to the riddle.

But there is a lizard more interesting still, and that is the crocodile. He stands alone among reptiles. His heart has two ventricles, and you would think that he ought to be included in the class of warm-blooded animals. But, no. The separation of the two kinds of blood takes place in the heart, it is true, and it is really true arterial blood which the aorta carries away from the left ventricle. But the right ventricle has two doors of exit. One communicates with the lungs, the other with the aorta ; and the latter has hardly performed its distribution in the upper part of the body when it meets, as it descends, with a treacherons tube bringing to it a current of venous blood. In this way only half the blood that comes from the veins passes on to be regenerated by contact with the air, and all the hinder part of the body receives nothing but the mixed blood common to reptiles, while the head and fore members enjoy the privilege of the superior orders. After this go and lay down your laws of classification ! Nature, while maintaining amongst all animals the same principle of life —the regeneration of the blood by oxygen—has in their construction followed many systems leading to the same result by different combinations, and which seem to permit the establishment of essential distinctions among them. Here is an animal who, if I may so express myself, is climbing up from one system to the other, and you would have to cut him in two before you could classify him properly, since his fore-quarters have risen to the warm-blooded animals, while his hind ones are left behind among the cold-blooded reptiles!

But there is something which even outdoes this.

On dry land the crocodile is timid, faltering, a bad walker, incapable of regular combat, and a man can manage him with a stick. One feels that he is betrayed by the hinder half of his body, through which circulates the only half-oxygenized blood. But when once he has plunged into the water his whole behavior suddenly alters; he is a ferocious being, high-mettled, indomitable, a savage enemy, redoubling his exertions, as if the entire mass of his blood had suddenly become arterial. Geoffroy St. Hilaire, who followed Bonaparte as a scientific explorer when he set out for the conquest of Egypt, the country of crocodiles, was deeply struck by studying on the spot this double life, which seems in a way to maintain two beings in the same body. He afterwards gave an extremely curious explanation of it in his work on the crocodiles of Egypt. Here it is; but I forewarn you that you will not understand it:

"The crocodile, when it is under water, receives by two canals into the cavity of the abdomen, a considerable quantity of water, which the animal can renew at will."

You are not much the wiser, are you? But wait a moment. We are soon coming to the fishes, and you will then see what an unlimited scope nature has allowed herself here. Not satisfied with two systems in one animal, she appears to have got hold of three.

If we continue the examination of this privileged reptile, we shall find many other infractions of the usual rules of his class. His tongue, certainly, is fastened to his mouth like that of the tortoise, so much so that the ancient Egyptians told the Greeks he had not got one; but his set of teeth clearly approach those of the lower mammals. You have probably heard a great deal of the strength of the crocodile's formidable teeth. Travellers have given them this reputation; but we have nothing to do with that now. They stand in battle array, in a single line, along the whole length of the jaws, into which they are sunk with genuine fangs, whilst the prongs of our little lizard are merely fastened to the surface of the bones which support them. Indeed, in one way, the crocodile is even better provided than the mammals. He possesses under each tooth one or two germs, the life of which lasts as long as that of the animal, and which are always there ready to replace the previous one should it chance to fall out. There are many ladies, and (not to be rude) gentlemen as well, who would, I am sure, give a great deal to have as many teeth at their service. Indeed, they may possibly think Dame Nature very unjust to have selected this great villanous beast rather than us as the object of a gift which they would have been so well able to appreciate. But we must not blame nature too quickly: she had her reasons. We, during our infancy, have teeth in reserve. Now, a reptile may be considered as an imperfect rough draft of a mammal; and the crocodile gives one thoroughly the idea of a mammal half-finished and fixed for life in a state of childhood. I am sorry that I cannot enter into full details, that you might see how far the idea is a just one. Moreover, in his character of a perpetual child, he is always growing bigger all his life long, and never seems able to die but by accident, hardly ever, I may really say, from old age. By specimens kept in captivity, it has been ascertained that their growth is very slow. Well, imagine their being only from seven to eight inches long when they come out of the shell, and that full-grown crocodiles have been found thirty feet in length, and calculate accordingly. You will not account for it under a century; and I should like to know what would become of this venerable child of more than a hundred years old if kind Mother Nature had not left him our system of milk-teeth to the end?

A curious peculiarity of these persistent teeth is, that they are hollow inside, so much so, that the bowls of tobacco-pipes are said to be made from them in Europe. I mention the fact, although of no great interest to you, for the benefit of any pipe-merchants who have not yet thought of sending for such things to Cairo.

But let us return to the efforts perceptible in the organization of the crocodile to raise itself to a higher level. The soft palate, as we called it (Letter VII.), is wanting in other reptiles; but here there is one which completely closes the entrance of the windpipe (the larynx). I announced, too, the disappearance of the diaphragm; and we bewailed together the loss of that servant of the good old times, whose touching history you must, I am sure, remember. But I reckoned without this wretched crocodile, who seems determined to give the lie to all we have been saying. He has a diaphragm, and one which acts well enough in the main, although it is pierced right through the middle, as if it were rather ashamed of being there, and wished to make up for dividing the body into two compartments, against all proper reptile regulations, by opening a door of communication between them. What shall I tell you besides? The lungs, not to be behind the rest of this aristocratic reptile's organization, are hollowed into cells much more complicated than those of his fellows. You find here no end of nooks and corners, which multiply opportunities of contact between the air and the blood, and so give the crocodile almost the respiration of the mammals, as he has already got pretty nearly their system of circulation.

With serpents, again, we fall very low. When we were speaking of the tortoises I told you that, in proportion as we come down in the scale, the digestive tube has a tendency to get rid of its accessories, and to assume the appearance of a perfectly straight tube. If any one were to cut open a serpent before you, you would see this final condition almost reached already. In the first place, the soft palate is entirely suppressed, and the mouth extends straight into the œsophagus, whose tube seems to run through the whole length of the body without interruption, with just four or five doublings towards the base, in that part which represents the intestines. An imperceptible swelling indicates the place where the real stomach lies within; but in another sense one may call the œsophagus, and I might almost add the mouth itself, its stomach. You shall see how.

The jaws of serpents are even in a more unfinished state than those of other reptiles. Nature has not taken the time to weld the different parts of them together; but these begin by not being very firmly joined, remember, in young mammals. The bones of the head, which support the jaws, are themselves movable, and can be detached from the skull if necessary, so as to allow the throat to open extraordinarily wide; thus it is not uncommon to see a serpent swallow animals much larger than itself. You will be horrified when I tell you that the anaconda, one of the giants of the family, swallows large quadrupeds at a single mouthful. What are our mouthfuls in comparison with his? however, it must be confessed, that his often take several days to go down. When the animal has rolled up his prey in his terrible folds, he pounds and kneads it till it is reduced to a kind of long roll, which he moistens with a copious slaver to make it slip down more easily. Then, attacking it at one end, he fastens this very expansive jaw upon it, and the gigantic mouthful slowly begins its journey; what was left outside the mouth, advancing little by little, in proportion as the digestion reduces what has entered to pulp, and sends it farther down. This is on great occasions; but in the case of more modest prey—a rabbit, for instance—the mouthful goes in whole at one gulp and remains stationary, partly in the œsophagus, partly in the stomach, while the powerful juices distilled by the walls of the latter are dissolving it.

You can see that a soft palate would have been quite useless here, and that the serpent has not much need of teeth to chew his food. Accordingly, his are nothing but simple prongs, like those of the lizard, and, like his, they extend over the palate, the more effectually to cut off the return of the swallowed masses of food. About a hundred and twenty have been counted in the throat of the boa-constrictor; but their number varies considerably in the different species. They are not organs of the highest order, and nature is not very particular about the quantity.

There is only one tooth among serpents of which she takes any particular care, and that is the venomous tooth which she has bestowed on certain species, and which serves them for striking down, as it were, the animals on which they feed. Let us study it in the rattlesnake, the most celebrated of this odious race. On each side of the upper jaw you may see, isolated from the others, and exceeding them all in length, a very sharp fang pierced through by a tiny canal, which opens into a gland placed at the root of the tooth. The bone which supports this little apparatus is very flexible, and when at rest, the fang, falling back, hides itself in a fold of the gum. When the animal wishes to bite, it springs up again, and the gland, compressed by the action of biting, sends into the little canal a jet of poison, which runs through it into the wound. As far as can be ascertained, this poison paralyses the victim and disorders the blood, which at onces loses its power, and no longer acts upon the organs as before; still it is only injurious when it has been carried by the current of circulation into the mass of the blood: if swallowed, it has no effect whatever on the stomach. Now do not look at me with such incredulous eyes, as if it were quite impossible any one should think of swallowing such a thing. You have no idea what a scientific man is capable of when he comes to close quarters with nature, for the purpose of extracting one of her secrets. He has his own fields of battle, where very often as much courage is displayed as on any other.

These two fangs, in which lie all the power of the animal, are of the greatest importance to him, and their want of solidity makes them liable to remain in the wounds which they have made. In consequence of this, they enjoy the same privilege as the teeth of the crocodile, and in a still greater degree even. Behind each poison fang lie in wait, not one nor two, but several sentinel germs, ready at the first alarm of a loss to set to work and re-supply the disarmed serpent with his venomous needle. So the serpent also lives in a state of perpetual childhood: he is always growing; and I could not tell you the exact natural limits of his life any more than of that of the crocodile. They are gentlemen who do not allow themselves to be very closely studied in a state of freedom. But these also grow very slowly, and some have been met with whose size had extended quite enormously from their first start. I ought to tell you, once for all, that this indefinite growth, joined to extreme longevity, is found in many of the inferior species whom we have yet to consider. It seems the portion of these unfinished creatures, in which nature has only as it were sketched in her work, and who seem vowed to endless youth, in testimony of the state of childhood they represent, a state transitory among the superior animals, but permanent with them. It belonged of right, therefore, to the serpent, which is the most unfinished animal we have yet met with, and who, at the first glance, seems almost reduced to a mere digestive tube, lodged between a vertebral column and a series of small ribs, whose number sometimes reaches three hundred.

The liver, which, with us, presents such a distinct and bulky mass, is here elongated into a thin cord, which runs the whole length of the œsophagus and intestine, to the walls of which it is, to some extent, attached.

It is the same with the lungs. There is rarely room for the full development of two in this narrow conduit, where everything has to follow the shape of the master of the house: one, therefore, is often merely indicated by a very slight protuberance; the other, presenting the appearance of a long tube, which extends nearly half-way down the body, and whose feeble action halts periodically at each of those monstrous repasts, after which the torpid animal becomes nothing but a huge digesting machine. We have now reached the extreme limits of that organization, the most perfect model of which we find in man, and which is no longer to be recognized in fishes.

LETTER XXXVI.

PISCES. (*Fishes.*)

We are becoming terribly learned, my poor child, and I am half afraid you will be getting tired of me. When I was little myself, I had rather a fancy for breaking open those barking pasteboard dogs you know so well, to see what was inside them. Why should you not, then, feel a certain amount of interest in looking with me into the insides of real animals? Still I cannot conceal from myself that the subject grows very serious at last, and that while I am busied in struggling to make myself intelligible through the endless crowd of facts which surround me, I am apt to neglect chatting with you as we go along. Happily, however, here is an opportunity for so doing.

Up to the present time we have lived, as it were, upon the explanations I gave you whilst studying the action of life in yourself, and all the organs we have met with since, have been only, properly speaking, reproductions, more or less exact, of those which you yourself possess. But, in passing over into the kingdom of fishes, we find ourselves in the presence of something altogether new, and I must go back to our old familiar style of talking to open the subject.

Take a water-bottle half-filled with water, and shake it well, and you will see a quantity of white froth come to the surface of the liquid. This is the air which, having been drawn in by the water, as it went up and down in the bottle, is now struggling to fly off again in bubbles as fast as it can. But the whole of it does not get away; a small portion remains behind, and melts, as it were, into the water, as a morsel of sugar would do, taking up its abode therein. This seems odd to you, but I will tell you how you may convince yourself of the fact. Get a small white glass bottle, slightly rounded, and thin at the bottom, if possible; fill it with water, and hold it for a short time over a lighted taper. If you do this carefully there is no danger. You will soon see tiny little balls, looking like drops of silver, rise from the bottom of the bottle, come up to the surface, and burst. This is the air which was installed in the water, as I described above, and which is now running away from the heat of the candle, as the inhabitants run away from a house on fire. After a time the whole will have passed off, and the little balls will cease to rise.

But what has all this to do with fishes? you ask.

A very great deal, I assure you, dear child. If there had been a little fish in your bottle, before it was exposed to the flame, it would have found means to make use of that air, whose original presence in the water you cannot refuse to believe after having seen it come out. It is with this air that fishes breathe in the water. They do so rather feebly, I admit; but, as if to make up to them for the small amount of the air placed at their disposal, it contains more oxygen than that we breathe ourselves, because oxygen, dissolving more readily in water than nitrogen, is there in greater proportion. Of course, you do not suppose that fishes have lungs like ours? I dare say you know the two large openings on each side of their head, called *gills*, by which the fishermen string them together to carry them away more easily? It is there you will find their lungs, to which the name of *branchiæ*, or gills, has been given, because they are so different from other organs of respiration that it was impossible to use one word for the two. The arrangement of the gills varies considerably in the different species, but their general form is the same everywhere. They are composed of a number of plates, consisting of an infinitude of leaflets, arranged like a fringe, and suspended by bony arches, into which plates and leaflets the blood pours from a thousand invisible canals.

First of all, then, we must see how blood circulates in fishes.

Like reptiles, their heart has only one ventricle, and yet the arterial and venous blood go each its separate way without the slightest risk of being mixed; but this is because fishes have not that double system of veins and arteries which hitherto we have always met with. The venous blood goes to the heart, which drives it into the gills, from whence it passes forward of its own accord, as arterial blood into the organs, under the remote influence of the original impetus from the heart, the newly-arrived blood incessantly driving the other before it into the vessels of circulation. It does not flow very quickly, as you may suppose; and as the heart is close to the head, its action is but very feebly felt at the extremity of the body, when this happens to be very long. Nature has, in consequence, taken pity on the eel, whose tail is so far from its heart, and provided accordingly. Dr. Marshall Hall has discovered near the tip a second, reinforcing heart, so to speak, which has its own pulsations, independent of the pulsations of the one above, and gives a fresh impetus to the sluggish blood,* which otherwise, as it would seem, would scarcely be able to accomplish the long return journey. Finally, even with an additional heart in the tail, the circulation among fishes is quite on a par with their respiration. They have a melancholy steward, whose legs are very heavy, and his pockets very light, and their life comes down a peg lower in consequence. It is always the same life nevertheless—you must never lose sight of that fact: it gets low in consequence of the imperfection of the machine, but without changing its nature, any more than the light in our different sorts of lighting apparatus. You remember that comparison of the lamp with which I began my story, and which you could not at the time see the full value of? From a dungeon lamp up to a candle, you have always grease burning in the air at the end of the threads of a wick. It does not burn equally well everywhere, and does not always give the same amount of light; but that is all the difference. From the mammal to the fish, it is always hydrogen and carbon (as we have said of the grease) which oxygen sets on fire in the human body at the fine-drawn extremities of the blood-vessels; only the fire is lower in some than others, and the life with it. Let us now look at the circulation of water in the fish's body.

The gills communicate with the mouth by a sort of grating, formed by the bony arches to which the gill-plates are suspended. The fish begins by swallowing water, which then passes through the grating and circulates round the innumerable leaflets of which each plate is composed, and among which creep the blood-vessels. It is through the thin coats of these leaflets that the mysterious exchange is made of the unemployed oxygen in the water and the carbonic acid in the blood. When this is over, the cover which closes the gills opens to let out the water, and a fresh gulp takes its place; and so on continually. When the fish is out of the water its gills fall together and dry up; the course of the blood already so weak, is interrupted by the breaking down and shrinking of the vessels, and the animal can no longer breathe; so that we have here the curious instance of a creature breathing oxygen like ourselves, who is drowned, if we may use the expression, in the air in which we find life, and lives in the water in which we are drowned. While he is in the water matters take another course, and his gills, moistened and supported, accommodate themselves perfectly to the contact of the air, which desires nothing better than to give up its oxygen to the blood, through the coats of the capillaries. Accordingly you will often see fishes—carps, for example—come to the surface of the water to inhale the air like a mammal or a reptile. This is a valuable resource, which supplements the parsimonious allowance of air given out to them by the water. There are even certain fishes whose gills, more firmly closed than those of others, have, in addition, a number of cells, which retain for a considerable time a sufficient quantity of water to preserve the gills in their natural state. These fishes can easily take an airing on land, where they breathe the air as you or I do, and are downright amphibians.

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* Many observers refer this to the lymphatic system.—TR.

The most celebrated of these is the *Anabas*, or "climbing-fish," an Indian fish, which not only can remain many days out of the water, but also amuses itself by climbing up the palm trees—it is hard to say how—and establishing itself in the little pools of water left by the rain at the roots of the leaves. But we need not go to India to find these wandering fishes. There is one of them living among ourselves who can walk about in the grass, and I was talking to you about him only just now—that is the eel. If you ever put eels in a fish-pond you must, I assure you, try to make it ageeable to them, otherwise they will have no scruple in setting politeness at defiance and moving off to seek their fortune elsewhere. In a country walk, when the dew is on the ground, you yourself may chance to come across one or two of these gentlemen, who have had their reasons for changing their residence, and whom you will see gliding so briskly along that they will deceive you into taking them for snakes if you have not a very experienced eye; so much so, that in certain parts of France where the peasants ate snakes formerly, they reconciled themselves to the sickly idea by christening them *hedgerow-eels.*

On the other hand, fishes may be drowned in water just as easily as ourselves if it does not contain air. The little fish who could have lived very well in the bottle we were just now talking about before you exposed it to the flame of the taper, would have died in it after all the air-bubbles had gone off; and I hope I need not tell you why. In the same way, if you leave fishes too long in a small quantity of water without renewing it, they suffer exactly as we do if the air which we breathe is not changed often enough. As soon as they have consumed what oxygen is in the water, it can no longer keep them alive. It is then, especially, you will see them come gasping to the surface to call upon the air for help. Those who keep gold fish in a glass bowl ought to know this, and to change their water oftener than is generally done. When we take poor little creatures from their natural way of life, and set a human providence over them in the place of the Divine one which has hitherto been their safeguard, the least we can do is to acquaint ourselves with the laws of their existence, so that we may not expose them to the risk of suffering by our ignorance. Finally, there are fishes whose gills, still more greedy of oxygen, will not act well except in thoroughly aerated water, and who would soon die in our tanks. This is the case with the trout, who is only happy in the waters of hilly countries; rich with all the air they have carried along with them as they fell from rock to rock. Now that people are beginning to do with fishes what has long since been done with sheep and oxen—keep them in flocks to have them always ready for use—you may perhaps hear a good deal said about vessels made expressly for the carriage of trout, with a thousand inventions besides for sending air into the water, and you will not have to ask the meaning of this now.

I promised last time that I would revert in the chapter of fishes to that marvellous transformation of the crocodile which has been explained by the torrent of water he draws into his stomach. You could understand nothing about it the other day ; but after what we have just seen the explanation suggests itself. Just as the extraordinary activity of life in birds is explained by that double oxygenization of blood, of which part takes place in the lungs and part in the reservoirs of air placed everywhere in the way of the capillaries, so this sudden increase of energy in the crocodile the moment it plunges into water may be explained by a second respiration suddenly established in the vast cavity of the abdomen, by the contact of the capillaries with the water which penetrates there. Hence the crocodile would then have, like the bird, a double respiration : only with him the one would be permanent and from the lungs, the other temporary and from the stomach. By this, on the one hand, he would rise up to the birds, since the blood encounters air twice over in its course, while, at the same time, he would plunge into the world of fishes, since the blood has to seek air in the water. The above, be it remembered, is only a supposition, and I ought to add that in this case there would be a good deal of danger in observing nature at work, for in front of the laboratory, where she is toiling in secret, stands on guard a row of teeth, by no means encouraging to indiscreet intruders. At the same time, if there ever were a legitimate conjecture, this is it. Everything seems to confirm it; and if it be true, we should have in the crocodile a specimen of each of the four systems adopted by nature for the mammal, the bird, the reptile and the fish. At first I spoke of two, then of three ; so that even in my addition I was modestly below the mark, and had really some grounds for recommending our friends the classifiers to beware what they asserted in this case.

Talking of puzzling classifications, this is just the place for mentioning the *batrachians*, who have been made into a class by themselves, but who most distinctly belong to two classes at the same time ; not like the crocodile by details borrowed from each, but by a fundamental change which takes place at a certain period in their organization. The batrachians are in reality reptiles, but they are reptiles which begin by being fishes, and real fishes too.

If you have ever strolled about in the country, you must have often come across those great pools of water which collect at rainy seasons in the ruts of deep lanes. Amuse yourself by looking into them in early summer, and unless the land is too parched and dry, the chances are that you will see quantities of little black fishes, almost entirely composed of a long tail joined to a large head, playing jovially in the muddy waters, and looking as if they had dropped there from the skies. These are young frogs—*tadpoles*, as we call them—and they are beginning their apprenticeship of life. Enclosed in each side of those great heads, they have gills, and they breathe in the same manner as fishes. Presently the two hind feet begin to bud out and grow, little by little; then the fore feet; finally, the tail wastes away till it disappears: and thus insensibly the tadpole is transformed into a frog. Observe here that the tadpole's gills share the same fate as his fish-tail; they wither and disappear by slow degrees, and gradually as they do so, his lungs are developed. The animal changes his class very quietly, and without ceasing to be genuinely the same, although it would be impossible at last to recognize the old individual in the new if you had not heard its history beforehand. This is one of the most striking exemplifications I know of the mysterious process by which nature has insensibly raised animals from one class to another, always improving upon her original plan without ever abandoning it.

On the shores of certain subterranean lakes which exist in Carniola, a country subject at this time to Austria, there are to be found batrachians far more ambitious than our frog—namely, the *proteans*. These cumulate rather than change: they become reptiles without ceasing to be fishes, if I may so express it; they develop lungs as they grow up, and yet keep their gills. I could tell you a thousand other particulars about these batrachians if I were to examine them all in succession; for it is a very motley family, in the bosom of which the transition from reptiles to fishes is in some imperceptible manner accomplished; from the frog, which the unanimous consent of mankind has always ranked among reptiles, to the axolotl or siren, who lives in Mexican lakes; and who, feature for feature, is exactly like a carp, with four little feet fastened under him. To be quite in order, the batrachians ought to have followed the reptiles, for their interior organization is the same; but how could I tell you about their gills without explaining that there was air in the water? and I did not want, for the sake of these intruders, whose babyhood-gills only just appear and disappear, to rob the history of the fishes of its most interesting points.

Let us be satisfied, then, with this passing glance at a dubious class, whose history is only a repetition of two others, and let us return to our friends the fishes. We have seen how they breathe, now let us look how they eat.

The modifications of the digestive apparatus are endless among fishes. The lampreys, who are placed in the lower ranks of the class, carry out to its fullest extent the type which we have already seen indicated in the serpent. The digestive tube is quite straight, without any perceptible swelling, and does not even go the whole length of the body. It comes to an end at some distance from the tail. Among some fishes an odd tendency begins to display itself, which we shall meet with again farther on. The digestive tube, after going downwards towards the bottom of the body, as we have seen it do so constantly hitherto, doubles back, and comes up again to the throat, under which it empties itself. In most cases the stomach is distinct; but it assumes a thousand different forms; as if nature had wished to try her hand in all sorts of ways in the construction of these imperfect vertebrates, before adopting the definite model which was to serve for the others.

The liver is enormous, and generally contains a great quantity of oil, the taste of which you will know if you have ever swallowed a spoonful of cod-liver oil ; but in most fishes its old companion, the *pancreas*, has disappeared. In its stead you will find, close by the outlet of the pylorus, the open ends of certain small tubes, which are shut in at their upper extremity like a "blind alley," and through which descends into the interstices a thick glairy fluid, given out from their sides or walls. The result is the same, you see, although the organ is different ; and, remarkably enough, these little tubes are wanting among fishes, which, like carp, have a species of salivary glands in their mouths, of which the others show no trace ; from which one may fairly conclude that these glands and tubes mutually supply each other's places. Here, then, you see an instance of the light which different animal organisations throw upon each other when they are compared together. In fact, this one establishes pretty clearly the real office of the pancreas in the higher races, exhibiting it to us as an internal salivary gland, intended to complete the work only begun by those in the mouth, in the case of lazy people who swallow their food too quickly.

There is the same diversity in the mouth as in the intestine. Some fishes, like the skate, have no tongue at all. Others, instead of a tongue, have a hard dry filament, very nearly immovable, and which one would think was put there like a stake, to show the place where the tongue is to be found in the more perfect organisations. There are even fishes, like the perch and the pike, whose tongue is furnished with teeth, or rather fangs ; an evident sign that it has forfeited the confidential position occupied by your own good little porter. You must know also that the perch and the pike, like many other of their fellows, have teeth all over the mouth. This invasion of the palate by teeth, which began in the lizard and the serpent, assumes alarming proportions here. It is not merely the roof of the palate which is spiked with teeth: above, below, at the sides, everywhere to the very limits of the œsophagus, the little fangs triumphantly stick out their slender points. It is impossible, therefore, to state their number. Nature has scattered them broadcast without counting, just as she has done with the hairs of the beard round the human mouth; and the comparison is not so impertinent as you may think. They sometimes form an actual internal beard, even thicker than our outer one, and which sprouts from the skin into the bargain. There is one fish whose teeth are so delicate and so close together that, in passing your finger over them, you would think you were touching velvet. This does not refer to the shark, mind. His teeth are sharp-cutting notched blades, hard as steel, arranged in threatening rows round the entrance of his mouth, and cut a man in two as easily as your incisors do a piece of apple. Others, such as the skate, have their mouths paved—that is the proper term—with perfectly flat teeth. The first time your mamma is sending to buy fish beg her to let you have a skate's head to look at. You will be interested to see the small square ivory plates laid close adjoining each other, like the tiles of a church floor. It is in fact a regular hall-pavement, over which the visitors glide untouched, and are then swallowed down in the lump; thus entering straight into the house without having been stopped by the inscription nature has placed over your door and mine—"Speak to the Porter."

But all this is nothing compared to the lamprey's entrance-hall, which differs from ours in quite another way. The lamprey, as I have already told you, ranks almost lowest among fishes, and consequently among vertebrate animals, of which fishes form the rear-guard. Indeed, it is almost stretching a point to consider her worthy to bear the proud title of a vertebrate at all; for the vertebral column, so clearly marked in other fishes, where it forms the large central bone, is only faintly indicated in certain species of lampreys, by a soft thread (or filament), which is rather a membrane than a bony chaplet and at the top of this mockery of a vertebral column is the creature's mouth. If you ever had leeches on, you will remember the sharp sting you felt when the little beasts bit you. Well, the lamprey feeds herself just in the same way as the leech does. Her mouth forms a completely circular ring, which sticks to the prey, and through which runs backward and forward a small tongue armed with lancets. This darts out to pierce the skin, and draws in the blood as it retreats. Round your lips well; dip them so into a glass of water, and draw back your tongue, and you will at once feel the water rise into your mouth. It is by a similar sort of proceeding that leeches relieve people of the blood they want to get rid of; and in the same way the lamprey draws out the blood of the animals upon which she fastens.

What a long way we have come already! How very far we find ourselves here from the little mouths we first talked about as chewing their eatables so prettily! With the lamprey we bid adieu to the class Vertebrata —the nobility of the animal kingdom—among whom nevertheless we must distinguish between the peer, who approaches nearest the person of his sovereign, and the inferior provincial lords who live at a hundred miles' distance. There is only one step from the lamprey to the *mollusks* or soft-bodied animals, and this is the course which animal organisation seems really to have taken in its progress. But nature never moves forward in a single straight line. In passing from the mollusk to the fish to get thence to the higher vertebrates, she turned aside in another direction toward a class of animals which rises far above mollusks, but which leads to nothing beyond.

One would think there had been a check here, as if the creative power, having discovered that it was going in a wrong direction, had retraced its steps; if it be allowable to apply common ideas and expressions to our conceptions of that Great Intelligence which has arranged the plan of the mysterious ladder of animal life.

The animals we must examine next, on account of their superiority to the rest, are insects. Small as the ant is, it would not be right to let her be preceded by the oyster.

LETTER XXXVII.

INSECTA. (*Insects.*)

Before speaking of insects, my dear child, it will be necessary, in the first place, to tell you to what primary division they belong and on what characters this division has been established. And here I find myself in a difficulty. We have been but too learned already, and now we run the risk of becoming still more so, if we commence an attack on the three primary divisions which follow the vertebrates. We shall have to encounter terrible names and tedious details, besides having to take into account a thousand things of which we have not yet spoken. We are going on quietly with the history of the feeding machine which occupies the middle of the body, and learned men never looked in that direction for the establishment of their divisions; between ourselves, it was not accommodating enough. They have fallen back upon the locomotive apparatus (*movement machine*) which affects the body all over, and which they have proclaimed to be the leading feature of the animal organization, without noticing however that it is, after all, but the servant of the other. It is true that the great divisions are more easily established upon this point than the other, because the differences are more decided. It separates what the other unites, and thus it is that nature carries on that beautiful combination which the Germans have so accurately named " *Unity in*

Variety," that is to say, she is always at work, as I have already told you, on the same canvas, but always embroidering it with a different pattern.

Wait! I have something to promise, if you are very good, and if this history (that of the feeding machine) should have given you a taste for inquiry. I will tell you another time the history of the movement machine, and there the classification of our learned men will come in naturally very well. In the meantime we will do as they do, and just shut our eyes to their divisions, in which the feeding machine can have no interest, because they were established without reference to it. We will content ourselves, then, without further pretension to science, with modestly examining the last transformations of our pet machine in the principal groups of the inferior animals; of which groups I will now tell you the names in their proper order. They are as follows: Insects, Crustaceans, Mollusks, Worms, and Zoophytes. You must take these names on trust; those which you do not understand will be explained in their places.

1. *Insects*.—I know not where it was I once read that there are said to be something like a hundred thousand different species of insects; and I verily believe this is not all. Of course we shall not attempt to review the whole of this formidable battalion. Let us take one of those you are most familiar with—the cockchafer, for instance—and examine what goes on in his inside. The history is nearly that of all the others.

"Fly away, cockchafer, fly!" says the song; and surely it is a bird that we have here, and a bird which will appear to you even more wonderful than those of which I have already spoken, when you have considered the simplicity, and at the same time the strength, of his organization. His mode of flight is rather lumbering, it is true; he is, in comparison with the large flies, what the ox is to the deer; but when you contrast the weight of his thick body with the delicacy and narrow dimensions of the two membranes which sustain him in the air, you may well ask yourself how those little morsels of wings, thin as gold-beater's skin, can carry such a mass along. In fact, they only accomplish this feat of strength by dint of an excess of activity almost startling to think of. When you run as fast as you can, how many times, think you, do you move your legs in one second? You would be somewhat puzzled to say; and so should I: but I defy you to count ten. Now the bird makes his wing move much oftener when he beats the air with rapid blows as he flies; but even he does not strike a hundred strokes in a second: and what is this to the feats of the cockchafer's wing? It is not hundreds but thousands of times that he flaps his wings in a second; and here let me hint, by-the-by, that when people seriously wish to find out a method of travelling in the air, they will lay aside balloons, of which they can make nothing in their present condition, and will set to work to fabricate machines with wings which shall beat the air as fast as those of the cockchafer. This sounds extravagant, but I have seen an electric pile fixed in a stand with glass feet, which caused a little hammer to beat thousands of times in a second: and surely the hammer could have been made to communicate its movement to a small wing! Forgive me this little castle in the air! The idea came into my head a long while ago, and the cockchafer has just reminded me of it. I will not, however, pursue the subject, neither will I offer to explain the method used for counting the beats of an insect's wing. That would carry us farther than would be desirable.

To return to our little animal. I leave you to imagine the enormous amount of strength required for such precipitate motion. We have spoken of the rapid course of the blood in birds during flight: who shall calculate its comparative rate in this fabulously wonderful locomotive, the cockchafer? And if we lift up the cuirass which encases it, what do we behold? Not a single trace of all the complicated circulation-apparatus you have learnt to know so well; neither heart nor veins nor arteries; only a quantity of whitish liquid, equally distributed throughout the whole internal cavity. Not a trace of lungs, nor any apparent means of renovation for this seemingly motionless blood; for blood it is, in spite of its color, or, at any rate, blood in its first stage of formation. It also has its globules—ill-formed, it is true, and altogether in balls—like those found in the chyle with us; which chyle, be it observed, is the same color as the blood of insects, and may also be considered blood in its apprenticeship. By what magic, then, is this raw, imperfectly-formed steward, who seems altogether stationary, enabled to accomplish exploits which would stagger his higher-bred compeers, agile and perfected as they are? Where does he pick up the oxygen necessary for such repeated movements, it being an established fact that no animal can move at all without consuming oxygen, and that the quantity consumed is in proportion to the rate of motion? Look under his wings for an answer. There, all along his body, you will observe a number of small holes, pierced in a line, at regular distances, and furnished with shutters of two kinds. They are the mouths of what are called *tracheæ*, or breathing tubes: and from them branch out a multitude of little canals, which, spreading in endless ramifications through every part of the body, convey to the whole mass of the blood, from all directions, the air which makes its way into them through the tracheal holes. In this case, you see, it is not the blood which seeks the air, but the air which seeks the blood; whence arises a new system of circulation, whose action is all the more energetic because it is unintermitting, and makes itself felt everywhere at the same time. A little while ago we were wondering at the twofold respiration of birds; yet this is far less surprising than the universally-diffused respiration of insects, who may well be able to do without lungs, seeing that their whole body is one vast lung in itself.

For the rest, do not trust to appearances, nor imagine that the blood of our friend the cockchafer in reality remains motionless around the air-tubes, idly drinking in the oxygen which is brought to it. Though not flowing in enclosed canals, it is not the less continually displaced by regular currents, which sweep through and renew this apparently stagnant pool. Nor is this the only instance of such a current presented to us by nature. Guess, however, if you can, where you will have to look for the counterpart to the circulation of the cockchafer. In ocean itself! But, remember, nothing is absolutely little or great in nature, who applies her laws indifferently to a world as to an atom. The blood of our world is water, which contains in itself all the germs of fertility, and without which, as I have already told you, life is impossible either in the animal or vegetable kingdom. The water of brooks, streams, and rivers, flows along in channels, which, when figured in a map, present to the eye of the beholder an exact picture of the system of circulation found in the vertebrated animals. But the waters of the sea are borne along, like the blood of insects, by a secret circulation, which cannot be represented on the map; *i.e.* by immense currents everlastingly in action, some on the surface, some in the mid-heart of the ocean, which drive it in ceaseless course from the equator to the poles, from the poles to the equator; so that the Supreme Intelligence, in His over-ruling providence, has ordained the same law to set in movement the immensity of ocean, and to effect circulation in the cockchafer's few drops of blood. In the latter we find the moving agent to be a long tube, which runs the whole length of the back, and is called the dorsal vessel (from the Latin *dorsum*, back). I told you that the cockchafer had no heart under his cuirass, but I spoke too hastily. The dorsal vessel is a *true heart*, but a heart devoid of veins or arteries, and thrown into the midst of the blood. It dilates and contracts like ours, sucks in the blood by means of side-valves, which act as our own do, and drives it back again into the mass by that valve at its extremities, which opens near the head. From thence arises a continued to-and-fro movement, which sends the blood from the head to the tail, and brings it back again from the tail to the head. But who would recognise, in this simple primitive organisation, where all seems to go on of its own accord, as it were, the same machine, with all its complicated movements, that we have been so long considering?

Well, in this apparently universal shipwreck of all the organs we know so well, there is yet one which survives, and remains the same as ever, namely, the digestive tube. I began by saying the insect is a bird. His digestive tube is formed upon the same pattern as that of birds, so that naturalists have bestowed the same names on the various parts in each of them. After the œsophagus comes a crop (*jabot*), very distinctly indicated; then a gizzard with thick coats, in which the food is ground down. The hen, if you remember, swallows small pebbles, which perform in her gizzard the office of the teeth in our mouths. The cockchafer has no need to swallow anything. His gizzard is furnished with little pieces of horn; real teeth, fixed in their places, which have a great advantage over the chance teeth picked up at random by the hen. I pointed out to you in birds, between the crop and the gizzard, a swelling or enlargement of the digestive tube, pitted with small holes, where the food is moistened by juices. The same enlargement is found here, covered all over with a multitude of small tubes, which might easily be mistaken for hairs, from which also falls a perfect shower of juices. The only difference is, that it comes after the gizzard, instead of before it, as in birds. Some naturalists, considering that the manufacture of *chyle* takes place here, have called it the *chylific ventricle;** a somewhat barbarous name, but one which explains itself, and might with truth be applied to the *duodenum* of the higher animals. Bile is poured in close to the hinder end of it. but you must not look for the liver; it has disappeared, or rather its form is entirely changed. You remember what the *pancreas* had become in fishes; *i.e.* a row of tubes giving out a *salivary fluid.* Such is exactly the appearance of the liver in the cockchafer.

Instead of that fleshy substance on which hitherto the office of preparing the bile had devolved, you see nothing but a floating bundle of long loose tubes, which, opening into the intestines, pour in their bile. The organ is transformed, but we recognise it again by the office it performs, which continues the same. As to the *pancreas*, it is wanting here, as in the fish with salivary glands; but in its place in many insects other tubes, acting also as glands, pour saliva into the *pharynx; i. e.*, the cavity at the back of the throat.

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* The corresponding protuberance of the birds bears a name, somewhat similar, but still more barbarous. I had passed it over in silence, because, I make the confession in all humility, I do not understand it; but a remorse now seizes me: it is called the *Ventricule succenturié*

As you see, therefore, everything is found complete in this tube of a few inches long; and you can also distinguish there a small and a large intestine. We are speaking of the cockchafer, which feeds on the leaves of trees; and it is for this reason I name some inches as the length of the digestive tube. This would not be longer than the body itself, had it been destined, as in the case of many other insects, to receive animal food. In fact, the law which we have shown to exist with regard to the ox and the lion, rules also over the insect-world; and whilst a radical change seems to have been made in the rest of the organisation, here everything is in its place, and we find ourselves in the same system.

Was I not justified in asserting that the unity of the animal plan is to be found in the digestive tube? and that this is the unchanging basis upon which the Creator of the animal world had raised his varied constructions?

How would it be, then, if we were to take the insect from its starting-point when it is only a worm, that is to say, merely and simply a digestive tube? for I am only telling you a small portion of its history here; a history you must know, which reveals a miracle still more wonderful than the transformation of the little tadpole into the frog! There is a brilliant-colored fly which comes buzzing about the meat-safe—the blue-bottle—do you know her? It is on her account that we put large covers of iron wire over the dishes of meat; but, perhaps, you never troubled yourself to think why.

But the truth is, she only comes there to deposit her eggs in the good roast-meat; and if she could get near enough to do so, you would soon afterwards see it swarming with little white worms, which would entirely take away all your appetite. These worms are only flies out at nurse, and they will find their wings by-and-by if you only give them time enough. Disgusting as they may appear on a dining-table, I assure you they deserve more interest than you may think. When we come to speak of worms, we will ask of them to let out the secret of the mysterious transformations of animals.

In the meantime, let us finish the observations we were making on the *perfect insect*, as this little creature is called when he has passed through the intermediate stages which separate him from the undeveloped condition. Forgive me, my dear child, here I am speaking to you as if you were a grown-up woman! This is because it is so difficult to explain things of this sort in any other way. And now that you have been introduced into the midst of the wonders of creation, you ought to familiarise yourself with the ideas and terms they have suggested to mankind. I began with you as a child, and great would be my triumph if I could leave you a grown-up girl! And I flatter myself that I have so far set your brain to work, under pretence of amusing you, that this hope is not altogether unfounded. I found it necessary to say this to you in confidence, because I have just read over our first conversations, and perceive that I have insensibly put you on a different diet from the one I began with. I am obliged to comfort myself by remembering that you have grown older since, and that you are now acquainted with a great many things which you had never heard spoken of then. And this is the secret of all transformations. We crept on at first over ground that was quite unknown to us; but as we went along, our wings must have begun to grow, and we are now able to fly a little!

Do not be afraid, however; I will exercise your tiny butterfly-wings very carefully just at present. We have only to examine what becomes of the *chyle* of the cockchafer after it has been prepared in the pretty little tube so finely wrought. We men have *chyliferous* vessels which draw up chyle from the intestines and throw it within a short distance of the heart, into the torrent of blood, where its education is completed. But the cockchafer, who has no other vessels than his air-pipes, and the *dorsal tube*, which has no communication with the intestines, what is he to do? Do not distress yourself about him. Make a tube of a bit of linen, well sewn together, and fill it with water. Sew it together as firmly as you may on all sides, the water will have no difficulty in escaping through the meshes. And this is just what happens with the little tubes found in animals, the coats of which are formed of interwoven fibres. By-the-by, from thence comes their name of "*tissue*," which they share in common with all the solid substances of the body, for all were once supposed to have the same general structure. The intestine of the cockchafer floats, did I not say? in the lake of blood which fills the whole cavity of the body. Well, then, the chyle has only to penetrate through these coats, to go where it is wanted. Hence it is not at all surprising that this blood should be white; and I have very good reasons just now for comparing it to our *chyle*. It is, indeed, chyle arriving directly from the place of its manufacture, without undergoing any other process; by which you may see that this little machine (of the digestive organs of the cockchafer), though differing in appearance so entirely from our own, is reducible to the same elements of construction, and that life is maintained by the same process as with us; namely, by the action of the air upon the albumen extracted from food. The cockchafer, it is true, is much further removed from being a fellow-creature of ours than even the horse; but the principle of life is the same with him as with us. And this is quite enough to cause children, who can feel and reason, to think twice before they begin to torture, by way of amusement, a creature whose life the God of goodness has subjected to the same conditions as our own. I speak this to those miserable little executioners who make toys of suffering animals: but the case is different with agriculturists, who have necessarily to contend with the devourers of their harvests, and whom, I admit, it would not be reasonable to bind down by the maxim of Uncle Toby.*

But now to finish with the cockchafer. We have got to examine one very important part of his body, that which in other animals has been the one most talked about ever since we began our study: I mean the mouth. You know that this is the essentially variable point in the digestive tube; so that you will not be much surprised, should we find he has something altogether new. The mouth of the cockchafer is composed of a great number of small pieces placed externally round the entrance to the *alimentary canal;* but the names of these, as they would not interest you, I will not enter upon with you; more especially as they refer to such tiny morsels, that you would have great difficulty in finding them again on the owner. Of these pieces only two are worth our attention. These are two bits of extremely hard horn, placed one on each side of the animal, which are called "*mandibles*," and which serve the cockchafer to cut up the leaves which he eats. Fancy your share of teeth being two huge things fixed in the two corners of your mouth, each advancing alone against the other till they meet under the nose! You would then attack your tarts with the weapons of the cockchafer! You would not, however, be able to bite them straight through from the top to the bottom, as is done by all the animals whom we have yet seen. It is this which so peculiarly distinguishes the insect's manner of feeding; for we have already been taught by the bird and the tortoise, that it is possible to eat with two pieces of horn. The cockchafer now shows us how to eat sideways; but this is merely an accessory detail. It does not affect what happens after the mouthful is swallowed. All insects, however, have not this peculiarity. The cockchafer belongs to the category of grinding insects as they are called, who bite their food: but there is the category of the sucking insects (or suckers), whose food consists of liquids; and these insects are furnished in a different manner.

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* I have introduced my Uncle Toby, who really has nothing to do here, in order to make you acquainted with a few lines of Sterne, which I wish I could place before the eyes of every child in the world.

"Go!" said he, one day at table, to an enormous fly which had been buzzing around his nose and had cruelly tormented him all dinner time. After many attempts, he finally caught him in his hand. "Go! I will not do thee any harm," said my Uncle Toby, rising and crossing the room with the fly in his hand; "I would not hurt a hair of your head. Go!" said he, opening the window and his hand at the same moment, to let the fly escape; "go, poor little devil; away with you; why should I do you any harm? the world is certainly large enough to contain both of us!"

In the innocent butterfly, who lives on the juice of flowers, the digestive tube terminates externally in a sort of *trunk*, twisted in several convolutions, which is nothing more than an exaggerated elongation of the two jaws, which become hollow within, and form a tube when joined together. When the insect alights on a flower, he suddenly unrolls this trunk, and sucks in the juices from the depth of its "corolla," as you would drink up liquid with a straw from the bottom of a small vial. Amuse yourself some summer's day by watching a butterfly in his labors amongst the flowers: sometimes he stops still, but oftener he is contented to hover over them; and, as he does so, you will see a little loose thread, as it were, move backwards and forwards as fast as possible: this is his trunk, which he darts out, while flying, into the corolla of the flowers, but which scarcely seems to touch them, so delicate is its approach.

Less inoffensive far is the trunk of the mosquito-gnat, and of all the detestable troop of blood-sucking flies. It is always a tube; but this tube is no longer a simple straw, but a sheath furnished with stilettos of such exquisite delicacy and temper, that nothing is comparable to them; and these, as they play up and down, pierce the skin of the victim, like the lancets of the lamprey, and, like them, draw in blood as they retreat.

Finally, amongst the *parasites*, the last and lowest group of insects, the stiletto-sheath is reduced to the size of a kind of little tube-shaped beak, which, when not in use, folds down like the fangs of the rattlesnake.

You do not know, perhaps, what a parasite is. The word comes from the Greek, and signifies literally, "*that which moves round the corn.*" The Greeks applied it to those shameless paupers who, to escape honest labor, made their way into the houses of the great, and enjoyed themselves at their expense. These parasites are little animals which settle themselves on large ones, to suck in, without having worked for it, the blood which the others have manufactured. The wolf hunts, fights, and tears its victim in pieces; and then, by means of that interior labor which I have spent so much time in describing, transforms it into nourishing liquid: and when all this is accomplished, the little flea, who lives hidden among his hairs, coolly draws out for his own use the valuable blood obtained with so much effort. There are many parasites in the world, my dear child—yourself, for instance, to begin with—who are perfectly happy to chew your bread without asking where the corn comes from which made it. But you have heart enough to see plainly that this indifference ought not to last, and that it is not honorable to go on living in this indefinite manner at other people's cost only.

You will some day have duties to fulfil, which you should accustom yourself to think of now, in order that you may prepare yourself for them beforehand, so that it may never hereafter be said of you that you passed through the midst of human society, taking from it all you needed, without giving it back anything in return. I advise you to conjure up this idea when the time comes to leave off playing and begin preparing to be of use. The sort of thing is not always very amusing, I admit, but you must look upon it as the ladder by which you will be enabled to rise from the degradation of a parasitical life. If you were in a well, and some one were to let down a real ladder for you to get up by, I do not think you would complain of the difficulty of using it. It is for you, then, to consider whether you would like to remain for ever in your present condition; for those who learn nothing, who *submit* to nothing, who are good for nothing, but to show off and amuse themselves—these remain parasites all their lives in reality, however little they may sometimes seem to suspect it.

At your age, however, there is still no disgrace in the matter. God shows us by the insects that little things are allowed to be parasitical; but on this subject I must return to a point in the history of animals which I touched upon before. I told you, in speaking of the crocodile, that the perfect state of the inferior animals is found represented in the infancy or less perfect state of those above them: and I may say the same again with regard to insects. All the young of the mammalia begin life as parasites, at least, as sucking animals: for they all live at first on their mother's milk, which is nothing more than blood in a peculiar state. But the name of parasite among insects is generally confined to those which take up their abode on the bodies of their hosts; though in common justice it might equally well be applied to the gnat and his relations, who, when once full, make their bow and are off, like the kitten when he has finished sucking. Well, without meaning to find fault, if we descend to the lower ranks of the mammals, we shall find among them many parasites in the received sense of the word. You remember the pouch to which the marsupials owe their odd name. The young kangaroo remains hidden for months in the pouch of its mother, feeding continually all the time; and it is then a strict parasite. During the four following months it goes in and out, and strolls about between meals, like other young ones of its class, and is then an animal at nurse affording thus a twofold example of the tendency of the great Creator to repeat Himself in His conceptions, here using for the infancy of the mammal the system invented for adult insects—elsewhere repeating the but terfly in the humming-bird, who may fairly be called a vertebrated butterfly, and reproducing the gnat in the vampire-bat, which I look upon as an enlarged and perfected revise of the original pattern, whence comes the scourge of our sweet summer nights.

And now, surely, I have said enough about these parasites, whose very name, I suspect, will make you shudder after my impertinent application of it. Never mind: it depends entirely upon yourself to get rid of whatever you find humiliating in the position I have hinted at. Do all you can to bring happiness to the parents on whom you live at present, and who give their life-blood so willingly for your good. God has made you very different from those little animals who have neither heart nor reason to guide them. Do not be like them, then, in conduct. By a little obedience and love—child as you are—you can pay them back what you owe, and they will never complain of the bargain.

LETTER XXXVIII.

CRUSTACEA—MOLLUSCA. (*Crustaceans and Mollusks.*)

Crustaceans.

Crustaceans consist of cray-fish, crabs, lobsters, and prawns, who may be considered cousins-german of insects, among which more than one naturalist has thought they ought to be placed. Like them they are divided into *grinders*, having the same action of the mandibles ; and *suckers*, who are also parasites, and have tubular sheaths containing stilettos. Mammals and birds are the victims of parasitical insects ; fishes have been reserved for the crustaceans, who do not disdain also to fasten upon their humble neighbors, the mollusks ; and even among themselves the little ones settle down on the great. A few live on land, but an immense majority in water, and seem destined to represent, in the aquatic world, the aerial class of insects, from whom, however, they differ in many ways.

The first difference is in that stony crust with which they are enveloped, like the cockchafer in his horny cuirass, and which you must know well enough if you have ever eaten lobster. Wherever we meet with horn in insects, we find stone in crustaceans. The jaws are stony, and the teeth of the stomach also. They are constructed on the same plan, only the materials are changed.

The digestive tube is less complicated, and consists merely of one large stomach, instead of that series of stomachs by which insects approach the organisation of birds. On the other hand, if among some of them the liver is reduced to simple tubes, floating loosely in the body, as we have just seen it in the cockchafer among insects, these tubes are generally so profusely multiplied, and press so closely against each other, that they form a large compact lump—a true liver, to sum up all—from which issues, as from ours, a *choledochian canal*, a bile-duct, *i. e.*, which passes out into the intestine at the entrance of the pylorus.

You recollect that canal of the liver which I was afraid to tell you the name of because it was so ugly? Well, this is that formidable name! Now that you have swallowed so many others, you must be strong enough to digest this.

No chyliferous vessels have been found in crustaceans, whence one may conclude that the chyle leaves the intestine by oozing from it, just as it does in insects. There it gives rise to an almost transparent sort of blood, a kind of sap, or lymph, which is put in motion by a genuine circulation-apparatus; a real heart, with all its canals. This heart has only one ventricle, and only sends blood in one direction, as in the case of fishes; but there is an essential difference between them, which we must point out. The heart of fishes may be called a venous heart, since it only receives venous blood, which passes thence to the gills, while that of crustaceans is an arterial heart. It receives the blood directly it leaves the respiratory organ, and sends it, not into one aorta, but into several arteries, which set out at once, each in its own direction, to nourish the various quarters of the body. This greatly resembles the system of circulation, with which we are already acquainted. The veins only are unsatisfactory. They form a kind of transition between the uncertain currents which convey the blood of insects from one end to the other of the cavity in which these strange organs lie bathed, and the closed canals of the higher animals. But they are not canals, properly speaking. The irregular intervals which separate the organs, more numerous here, are enclosed by membranes, between which the venous blood pours, and naturally the chyle also. The whole thus arrives at certain excavations formed at the place where the legs are jointed on to the body—reservoirs, so to speak—where the real canals come to carry it off and convey it away into the gills.

It is, in fact, by means of gills that crustaceans breathe in their character of aquatic animals. These gills are made nearly upon the same model as we have already seen in those of fishes; and although their form and arrangement differ in different species, yet the principle is always the same: they are tufts of leaflets springing from stems, up and down which run two tubes; one which brings the blood from the venous reservoirs, the other which carries it to the heart. Crabs, lobsters, and crayfish, who are the "file-leaders" of the crustacean tribe, have gills enclosed in the body, as fishes have; but the circulation of the water goes in a contrary direction to theirs, as does that of the blood. Instead of entering at the mouth and going out at the sides, as we have seen, it enters at the edge of the bony shell which covers over the body and comes out near the mouth—a merely accidental detail which does not in any way alter the play of the apparatus. All these animals are equally adapted for swimming and for walking, crabs especially, their gills accommodating themselves without difficulty to contact with the outer air, as we have seen among certain fishes; so that one might class them with amphibians. There is even one crab who has acquired the name of *land-crab*, because, although he has got gills, he dies in water, the small amount of air he can get out of it at a time being insufficient for him, and who, therefore, lives constantly on land. It is true that he seeks out damp spots, for his gills would also fail him if they became parched, and, like the fishes who make excursions on dry land, he is provided with an internal reservoir, which is always filled with a certain quantity of water.

Some aquatic crustaceans have the labor simplified by external gills, which hang down into the water, sometimes depending from the stomach, sometimes from the legs. In France you sometimes see at a table certain little animals, very like shrimps (*squillæ*), the bases of whose hinder legs are fringed by slender tufts, which are in fact their gills. They find themselves placed there just within reach of the venous blood; for in the body opposite the bases of the legs are little cavities in which it accumulates. Now these gills can only act when under water, and so the squilla dies as soon as he is removed from that protecting element. For the same reason they cannot be kept long, nor travel far, much to the regret of those who like them and live at some distance from the sea.

There are other crustaceans, next-door neighbors of the squilla, whose gills are still more simplified. Here the legs themselves are turned into extremely thin plates, which play the part of gills, and are thus organs for two purposes, serving at the same time to swim and breathe with.

We have in our house one little crustacean, the only one I know of who associates with men, and that is the wood-louse. You must know the little grizzly beast, which rolls itself up into a ball whenever it thinks itself in danger, and who would be taken for an insect by any-one who was not taught otherwise. The wood-louse has neither gills hanging down outside, nor anything inside her body which resembles the breathing apparatus of her great relations. But, on examining her closely, you will perceive all along her stomach a series of little plates, which are her breathing-organs, and which come under the class of gills, because, like other gills, they require a certain degree of moisture to make them act properly. You will never, therefore, see a wood-louse strutting about in the sunshine, where he would dry up far too quickly ; but if ever you get into a dark, damp corner, there you have every chance of finding one.

Animals who breathe through their legs and through their stomachs! You are astonished, and ask, What are we coming to ? What would you say, then, if I were to go really to the depths of the crustacean world ? We should find there such extraordinary beings as you can form no notion of, for they all live down below in the sea, and have no special breathing-organ at all, inasmuch as they breathe through the whole surface of the body. Do not exclaim yet! I will soon show you one whom you know perfectly well, and who has no other way of breathing.

But we must keep to the higher crustaceans, if we want to judge of the class. By going too low, we run the risk of not seeing clearly. Animal creation is here on a system of experiments : and they are so endlessly multiplied, and exhibit such a profusion both of deceptive resemblances, and of differences which disappear by transformations, that classification no longer knows which way to turn. Worms, crustaceans, mollusks ; to which group do these and those belong? To which ever we like to refer them, for these groups represent nothing definitely determined in the plan of creation; and though easy to be distinguished from each other in the higher branches, they become confused together in the lower, like mountain summits which spring from a common base, at the foot of which they are all united together.

On this account, my dear child, you will, I am sure, excuse me now and henceforth, from entering into details of all the horrible beasts which swarm in the shallows of the animal world, and whom learned men have in their wonderful wisdom muffled up in terrible names, in order to prevent children from coming near them! What would you have thought of the poor little squilla, so prettily baptised by the fishermen, if I had taught you that it belonged to the order of *Stomatopoda*? You will scarcely be able to pronounce the word; but that is no fault of mine, it is spelt so.

We will content ourselves, then, with having taken a glance at the most clearly marked individuals; and as I said to you just now, it is by them that we will arrange our inventory of the groups. Here, as you may have already remarked, instead of continuing to wander from the original model whose gradual deterioration we have been following all this time from one class to another, it would seem that we are retracing our steps, and regaining some portion of the lost ground. This is because insects, as I have already stated, are an exceptional case—an idea apart from the great general plan—a by-lane turning off from one side of the great line of animal creation.

The crustacean, less perfectly worked out than the insect assuredly, but more regular, forms, so to speak, the connecting line between that tiny masterpiece of fancy, so incomplete in its exquisite organisation, and the shapeless but better constituted lump of the mollusk, who conceals under his heavy shell the sacred deposit of real organs, those which we expect to find always and everywhere. An insect outside, though less refined it is true, a mollusk within, the crustacean reminds me of what among us is called an *amateur*—that mild lover of the arts who holds a middle place, as it were, between the artist and the common citizen.

I regret that you are not at present quite able to appreciate my comparison fully : but put it by, in reserve, if possible, in your memory ; you will find out hereafter how just it is, and it will, perhaps, help to prevent you from always setting the lively, noisy artist, above the quiet and silent citizen. Let this, however, be between you and me. If they could hear us talking, neither artist nor citizen would forgive me, and the amateur still less.

Mollusks.

There is one mollusk universally well known—namely, the oyster—so we will choose him for discussion. To look on one's plate at that little mass of soft, compact substance, one feels inclined to ask what there can possibly be in common between it and us ; and if you were to declare that there was not the faintest trace of resemblance between the organization of the oyster and our own, I should not be surprised. Wiser people than you have been caught tripping there ; not that they were ignorant of the points in which the oyster resembled us, but they paid no attention to them. Viewing it in other respects, they declared that it was of a structure completely different to our own ; and that, in the construction of this machine, the Creator had worked upon a particular plan, laid aside afterwards as useless for any other purpose.

I should like to get hold of one of those Academicians, with thirty-six plans, and confound him before you, in proof of his relationship to the oyster, by showing you at one sitting that there is an oyster in himself; nay, further, that he is nothing but an oyster, revised, amended, and considerably enlarged. And do not imagine that I am only using a figure of speech here, as the professors of rhetoric call it; which would be in bad taste: I am speaking literally, and to prove the existence of the oyster in question in our Academician, I shall only ask permission to perform a slight operation upon him. You exclaim at this; but do not alarm yourself, for it is only an operation on paper, he will not die from it. See now, I cut off his head, his two arms, and his legs; I take out of his body the vertebral column and the ribs; I gently place what remains between two shells; and . . . . there is my oyster. I willingly admit that it is more carefully elaborated and richer in details than its sisters in the oyster beds; but all the principal organs are to be found in them also, and they positively are beings of a similar construction: you shall judge for yourself.

The mouth—for there is a mouth, though one must look closer than the oystermen do to discover it—the mouth is exactly what the gullet (œsophagus) would be in a man whose head had been cut off; that is, a truncated tube. Then comes the stomach, situated in the very midst of the liver; which latter may easily be distinguished, even by the most cursory glance at luncheon, from its dark color. The intestine also goes right through the liver, doubling backwards and forwards several times: and thus the digestive tube supplies itself with bile from the cask (to borrow a commercial expression); and this saves the expense of a bile-duct (choledochian canal), which would be an unnecessary mode of conveyance in this case. The animal lives in water; consequently, instead of lungs he has gills:* these are those thin, finely-streaked plates which make a fringe at the very edge of the shell. Finally, on leaving the gills the blood is received by an arterial heart, with only one ventricle like that of the crustaceans, in the shape of a small pear, similar to ours, having an auricle, and an aorta, branching out so as to distribute the blood throughout the whole body. And now what do we find here, let me ask you, in this mutilated man, reduced to the soft portions of the trunk, whom I have been imagining? A heart, with its arteries; lungs; a liver; an intestine; a stomach and an œsophagus: that is to say, merely and simply the organs of nutrition. That is all, or very nearly so.

As you perceive, then, all the elements of our own feeding-machine lie between the two shells of a mollusk; in a rough state as yet, it is true; incomplete, and unruly; as in the case of the intestine, for instance, which in many of these creatures passes without ceremony through the heart: but even so they are quite sufficiently indicated to prevent their being mistaken. Now this machine, it is in vain to deny it, is the animal itself; by it it lives at first, and it is this which dies in it last. The other matter (the locomotive power), important as it may seem to us in higher races, only holds a secondary position in reality: the proof of which is, that here is an animal reduced absolutely to a mere feeding-machine, who still lives, whilst there yet remains to be found one who has nothing left but his movement-machine, and who can yet exist. We cannot disown this primitive animal, for we have it within ourselves; lost, so to speak, in the midst of the accessory organs which are successively added to it in proportion as we rise in the animal scale, but still preserving its own life, its personality, if I may use the expression. Listen to this, for here is a history well worth hearing.

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* The land-snail has lungs.

I will explain to you, hereafter, how all the actions of the movement-machine are performed by means of a network of nervous threads (filaments), whose centre of impulsion is in the brain. How our will acts upon the brain, and gives its orders to the muscles through the nervous fibres, I will not offer to explain: it is a fact, let that suffice us. You say to your foot, "Forward!" and off it starts; "Halt!" and it stops. Here is an organ under command, a servant of the brain, where we rule ourselves: with or without explanation, no one will ever dispute this. The oyster, who has neither head nor brain, has, as his only instrument of action, certain little masses of nervous substance scattered right and left, which are called *ganglions*. These communicate with each other and with the organs by nervous cords, which are interlaced in all directions, without having any common centre, and which give the impetus to all parts of the animal.

Well, the human oyster presents to us exactly the same nervous organisation. It has its ganglions and its nerves to itself, which are put into communication with the brain by some threads strayed among his own, but which are not under its orders, and which treat with it on equal terms. You remember, perhaps, the little republic talked about when we first entered the digestive tube; you have now the explanation of it. This republic is the original animal; it is the feeding-machine. I cannot describe it, and the kingdom of which you are queen, better than by comparing them to two States having diplomatic relations with each other, who exchange dispatches and reciprocal influences; and as to the importance of these respective influences, if one were to compare them I scarcely know to which side the balance could incline.

We shall return elsewhere to this detail, one of the most interesting of our organisation, and which here finds its natural explanation. For the present I will content myself with reminding you that, since the earliest days of human civilisation, all philosophers, all poets, and all moralists, whether sacred or profane, have borne witness to that double life within us, that inward being, blind and deaf, whose disordered impulses so often carry trouble into those higher regions where will and reason sit enthroned. Behold him taken in his lair at last, this mysterious being. I have just unveiled his origin to you. And here, dear child, I must shelter myself behind a profession of faith. There will not be wanting people to tell you that it is degrading man far too much to look so low for the sources of his organisation, and that this sentence—*the human oyster*—which expresses my idea so well, is neither more nor less than blasphemy. Let them talk, but adopt their opinion only when they have proved to you that man had a special Creator, and that the oyster came from a different hand from ourselves. I should like to know with what face we could venture to complain, poor worms that we are, because it has seemed good to our common Father to carry forward in us his previous creations, and in what respect human dignity would suffer from this contact with a being who, like us, is one of the works of God. That human pride may suffer thereby, I admit, and I am glad it should; but if God has included all creation in His love, we may well include it all in our respect. Whence comes our superiority at all, but from the gratuitous gifts of Him who has made us what we are? Is it to lose it, then, to find ourselves side by side with inferiors whom the Divine benevolence has visited like ourselves? Surely not. But enough of the oyster, who has never, that I am aware of, heard such strange discussions sounding in his ears before. I have no time nor courage now to speak of the other mollusks, who offer more or less the same system of organs which I have just described. I must hasten on to the Worms, who give us the last clue to the great enigma of the animal machine.

LETTER XXXIX.

VERMES--ZOOPHYTA. (*Worms and Zoophytes*).

Worms.

THE worm of worms, the one you know best, is the earthworm: so he shall have the honor of representing his group.

He will not take much time to describe. He is, in brief, a tube, open at both ends, so as to allow food to come in and go out. That is all.

I talked to you before about the ruminants, those food-manufacturers who are employed in cooking victuals for the stomach, and in disengaging albumen from the coarse materials among which it is apparently lost, so as to give it out again in a more acceptable form. The ruminant has other workmen under him, whom I keep in store for you as the last of the eaters, and who prepare the raw material for him. These are the vegetables, who seek out the elements of albumen in earth, water, and air, those final sources of all alimentation. The earthworm also is a *preparer*, but in a peculiar way. Look along the garden-walks in summer-time, after rainy weather: you will see here and there, little heaps of earth moulded into small sticks, like dough which has been passed through a tube.* This is the damp soil which the worm has passed through his tube, after extracting from it, during its passage, the various elements of fertility he requires for the support of his life. This is what makes him so particularly fond of garden soil, because it is richer in animal and vegetable matter than common earth, and proves therefore more nourishing food. The worm, then, feeds on the fat of the earth, which he converts into azotic aliment for the use of moles, hens and Chinese. It only figures, it is true, for want of something better, in Chinese cookery, so profusely hospitable for all that; but the hen doats upon it, and you do not despise it yourself when it comes back to you in the form of a chicken's wing, that second transformation of the matter of which the soil of your garden is composed. It is told of certain savage tribes, the victims of constant scarcity, that they swallow little balls of clay in order to keep down their hunger; and during the great famines in India the distracted inhabitants may, we are told, be seen digging up the banks of the rivers to feed on the fertile clay in which the splendid vegetation of their country is developed. This is a desperate trial of that primeval system of alimentation which answers perfectly with the worm, but becomes a cruel mockery in the case of an organisation

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* M. Macé's account of the earthworm's life seems founded on the assumption that it extracts its nourishment from the earth itself,

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i. e., from inorganic matter, *as vegetables do*, to use his own words. But this notion is so entirely at variance with present received opinions, and also with the fact that the animal possesses a gizzard for digesting, as well as an intestinal canal, that it has been necessary to make considerable alterations in the description. To dismiss his theory of the primitive animal, etc., altogether, was, however, impossible, without omitting the whole chapter; but as young heads are not likely to trouble themselves about it, and it is very innocent in itself, it will do no harm; subject to this warning, that M. Macé has taken the earthworm for a more simply organised creature than it really is.—Tr.

as exacting as that of man. Let us examine a little more closely, then, this wonderful tube.

At first sight one notices, to begin with, that it is composed of perfectly distinct rings, all quite alike. Inside as well as out each of these rings is an exact repetition of the other. They are all formed of circular muscles, enclosed between two coats, which extend from one to the other. A series of ganglions, arranged in the form of a necklace along the whole length of the body, set in motion the muscular system of the rings, each of which possesses its local centre of impulsion. Each feeds itself in its place from the nourishing juices with which it is in contact, the interior coat enjoying the double property of distilling digestive juices and absorbing digested ones. These juices pass through the muscular partition, and proceed to bathe the outer coat, which plays, at the same time, the part of coat and lung, and affords a passage to the air through its soft, damp surface, like that of gills. From all this results a fine red blood, such as we have not met with since we left the reptiles, and which is manufactured in all parts of the body at once.

Each of these rings, then, the worm's only organs, is a little eating machine to and for itself, and at the same time a little movement machine also ; in fact, a complete animal. Each one could, if necessary, nourish itself and live apart ; and this is what he really does. Learn hence, to despise nothing in nature. One tramples an earthworm under foot, and there below one's heel lies a little revealer of secrets, whose organisation throws the most unexpected light upon one of the greatest mysteries in our own life.

I said to you before, and I felt at the time that it was rather beyond you, that " each one of our organs is a distinct being, which has its particular nature and special office, its separate life consequently; and our individual life is the sum total of all these lesser lives, independent one of the other, but which nevertheless blend together, by a mysterious combination, into one common life, which is diffused everywhere, but can be apprehended nowhere in particular."

The study of the worm admirably explains this out-of-the-way sentence. And here observe my adjective—my out-of-the-way—for it is a case in point. We may call it a literary worm; a worm of four rings, each perfect in itself, but yet compounded together into a whole with its own idea.

That which makes this idea of life most difficult to comprehend is, that one cannot prove it by a direct experiment, since there is not one of our organs which could exist separately from the others. Although independent in their special action, yet these multiplied lives are nevertheless in a state of absolute and mutual dependence, from the imperative need they have of each other to make them act, each having for its share only one particular function, the effect of which extends to all the others. This is called the division of labor; and if you still do not understand me clearly, I will explain it in another way. The heart sends to all the organs—does it not?—the blood, without which they could not live: separated from the heart, the lungs would die immediately. It is to the lungs the blood goes to find the air, without which it could not maintain life. Separated from the lungs, the heart would die immediately. There is nothing belonging to us which can avoid the inexorable requirements of blood and air; consequently, there is nothing which can live an isolated life.

I will borrow a simile from human society which you will understand at once. In civilised countries, where division of labor is established, the tailor makes clothes, the mason makes houses, and the baker makes bread. If you could throw them each alone by himself into a wood, the mason would not be able to dress himself, the baker would sleep in the open air, and the tailor would not know how to make bread. Or rather, as not one of them can carry on his trade without the co-operation of a multitude of hands, they could none of them do anything at all. Each completely independent in his work, yet each dependent upon the others, both for living, and even for being able to work, our workmen can only act when they remain bound in close union with the vast society of which they form a part; and our organs—those other laborers whom you have seen working for so long—our organs are just in the same predicament. But in the primitive societies, among savage tribes, where each man can make his clothes, his house, his bread (when he has any), and everything else for himself, you might take such an individual if you liked, and separate him from the rest of the tribe, and he would go on living as before. And so with the rings of the worm, that primitive society of organs. Each of them is a universal workman, who knows how to make everything. Separate him from his fellows, it will not disturb him at all, and he will go on living as if nothing was the matter.

I still remember some profound reflections I indulged in one day some years ago whilst leaning on my spade and looking at a worm that I had just cut in two, and whose two halves were walking off one on each side.

"There was only one creature here just now," I said to myself, "and now there are two! Have I had power, then, to create one with a stroke of the spade?"

I had not then got hold of the key which I now give you, and to which no possible objection can be raised. If there are two beings after the stroke of the spade it is because there were two before. Nay, there were even many more, if we may trust to the "Manual of Zoology" by Milne Edwards, a very good book, excellent for an old scholar like myself, and which I have found very useful in my country-home, as it has enabled me to relate to you one after another the mysterious wonders of life. He says that, "if one cuts an earthworm across into two, three, ten, or even twenty morsels, each of these morsels will go on living in the same way as the whole, and will form a new individual."

Twenty! that seems to me a great many, because, as far as I can trust to my brief observations as a gardener, it is necessary that some of the rings should remain united together and afford each other mutual support, in order to succeed in repairing the bleeding breaches; but I would much rather believe it than try the operation. My mind is easy when I am defending the plants that I have sown in my garden from the gluttonous worm who would rob them of their food; but it would not be so if I were cutting them up on my table to learn something about them.

Besides, there is no need of an operation to convince oneself of the particular life of each ring. There is one worm, well known by name at least, though happily not to be met with every day, and that is the tape-worm, who establishes himself in the intestine of man, and lives on the chyme, as the other worm does on garden-mould. They call him the *Solitary* worm in France; and if ever one might suppose a creature appropriately named, it would surely be him; for certainly there is not much society to be looked for in the dwelling he chooses for himself! But it happens that this pretended *solitary* worm, with his unlimited chain of rings, is only a long row of perfectly distinct beings, so distinct indeed that, from time to time, some of the rings let themselves go, fall off like ripe fruit, and go away to live elsewhere, ready to become the nucleus of a new set, if a happy accident carries them into another intestine, the only place favorable to their development.

At last, then, here is a corner of the curtain raised; here we see the associated organs which constitute an animal, living for once a life positively and in all respects their own. We are now satisfied about this; and when at another time we find them bound together in the chains of a union too ingenious to be severed with impunity—which we shall discover by seeing their action stop at the moment of separation—we shall know the cause.

Do not think, my dear child, that a wretched earth worm can prove nothing as regards other creatures. The worm is the starting-point of all the organisations which come after him. Of what is he composed? Of a tube which is itself composed of rings. Well, it is upon this very tube that the whole animal machine has been founded: and these rings, as they expand and modify themselves in a thousand different ways, give birth to all those varieties of being which drive classifiers to despair, because they will not understand that there ought only to be one animal, since there is only one Creator of animals. Now, this animal is a digestive tube served by organs; it is a worm, *i. e.*, which goes on constantly embellishing itself. I said to you long ago, and at a time when you scarcely knew anything, "Have you ever observed a worm or a leech in motion? You see a successive swelling up of the whole surface of its body as the creature gradually pushes forward, as if there was something in its inside rolling along from the tail to the head. Such is precisely the appearance which the œsophagus would present to you as the food passes down it, if you had the opportunity of seeing it in action; and this has been called the *vermicular* movement, in consequence of its resemblance to the movement of a worm."

And afterwards, in speaking of the intestine:

"If your body were made of glass, so that you could look through it to watch the intestine at work, it would appear to you like an enormous worm, coiled up into a bundle, heaving and moving with all its rings at once."

You have now got hold of the secret, namely, that from the beginning to the end of the digestive tube, its movements are those of a worm. What a wonder! and that the worm is a digestive tube which can walk. This worm, or this tube, whichever you please to call it, has never ceased crawling under our eyes since we began this study. Lost sight of in man in the midst of the riches he has picked up on his road, invisible and coiled backward and forward in his palace like an Eastern despot who leaves everything to be done by his slaves; behold him here in his first stage naked, shivering in the air, forced to go off himself and alone to his pasture-ground! But in the coarse earth with which he fills himself I can already see the delicate chyme which his numerous servants will prepare for him later on, and into which the heart-tree will one day send down its roots—the chyliferous vessels.

A short time ago I called the oyster the primitive animal, but I was in too great a hurry. The worm is the real primitive animal. He is to be found in the oyster, as the oyster is to be found in us; and that poor little beast is, by comparison, an animal of high pretension, who would be shocked, I am sure, if he could understand what we are saying, and heard us assert that he is nothing but an embellished worm.

Zoophytes.

Two centuries ago it was believed that below the worm, animal life, properly so called, ceased, and the creatures whom I am about to introduce you to were supposed to be animated plants rather than living organisms. Hence their name was especially chosen to express that double nature by which they were thought to have a share in two kingdoms at one time—viz., the animal and vegetable—*zoon* in Greek meaning animal, and *phuton* a plant. Zoophytes were set down as animal plants.

And although later discoveries have long ago established the fact of the complete animality of zoophytes, the old name is still in general use. But you must not let it deceive you. Zoophytes are animals every inch of them, however low in the organic scale, and although many of the compound ones imitate the growth of plants and shrubs so exactly in their mode of spreading that it is only by the closest observation we can persuade ourselves they do not belong to the vegetable kingdom. Of these there are the delicate buff-colored, prettily-branched, horny specimens found on the shore, which make so beautiful a variety in seaweed pictures among the red and green colors of the real seaweed; but of these also are those wonderful stony shrubs which grow on the submerged rocks of islands in warms seas, and the material which you know so well by the name of coral—the very coral of which the necklaces and bracelets in the jeweller's window are composed.

In all cases of compound zoophytes, however, there is one great point which they have in common with the worm, viz., that there is an association of distinct lives acting unanimously; or, rather, to the same end. Plainly as this is seen in the worm, it is still more obvious in the zoophyte. There is no need here either of cutting them up yourself or of taking other people's dissecting operations upon trust. It is enough to use your eyes, with the help, it is true, now and then, of the microscope's clearer sight.

You know the old oak-tree which stands on the outskirts of the wood, and is called among the country folk *the patriarch?* Now, this is clearly not an individual, but a nation. It is not a tree; it is a forest. Nay, may I not call it a green field? For this trunk, so truly venerable from ages of growth that one feels inclined to bow to it as one goes by, is, in fact, a collection of structures, accumulated by countless generations of fleeting herbs, *i. e.*, leaves, not one of which has lived for the space of a whole year round. Every spring some thousands and thousands of buds open to the sun; each one, therefore, affording a passage to a little green point; and this point is an oak, who comes into the world, like the first oak, the grandfather who formerly came forth from an acorn, under the form of an herb or tender leaf, which a sheep might have browsed upon. Yet it is so thoroughly an oak, that you have only to take out the bud carefully before it has expanded and fasten it into another one's place upon a tree of the same family, though of a different species, and it will produce an oak of the same sort as its old companions, and which will, as it progresses, look quite a stranger among the indigenous branches. This is the secret of what the gardeners call *grafting*, and I advise you to try the operation upon rose-trees, for nothing is more amusing. When the autumnal frosts set in, all these troops of new little oaks die, and deliver up their leaves to the wind; but they leave behind, as their summer's work, a tiny morsel of new wood, upon which, if you look carefully, you will see a fresh bud dawning—the hope of the coming season. And thus the great life of the tree is perpetuated from century to century by an uninterrupted succession of transient lives, reminding one in all respects of the life of a nation; and the similitude is complete in the evergreen trees, where the new leaf makes its appearance before the old one has quitted the stem.

And such is the life of the great stone trees and shrubs of various kinds which grow under tropical seas, and whose makers and inhabitants are the coral polyps, the undoubted heads of the Zoophyte race.

But before considering the *polypidom*, or external dwelling (otherwise called the *cœnecium*, or "common house"), you must learn something of its originator, the little *polyp*, who lives inside, and belongs to a family so widely spread over the face of the earth, that there are scarcely any waters, whether salt or fresh, without them.

In your own neighborhood, if you know how to look for them, are to be found on the banks of ponds, or along the borders of streams which lie sleeping in roadside ditches, extraordinary beings which, a hundred years and more ago, completely bewildered the good Dutch naturalist Trembley, who had taken it into his head to study them. Picture to yourself some very tiny bags made of a kind of jelly; gray, brown, or, most commonly of all, green in color always transparent, and fastened by their base to the stalks of *carex*, water-lentils, or the confervas, which grow in still water. A hunter on the watch, this bag shoots out on all sides a number of slender threads, like so many whip-lashes, arranged within a circle round the edge of its opening or mouth; and with these whip-lashes all the animalcules which come within reach are entwined, stifled, and carried away to the ever-yawning little gulf, where they are digested in less than no time. Whatever will not digest comes out afterwards by the way it went in. Of what becomes of the results of this digestion it is impossible to form an idea. Were you to cut up the bag and put little morsels of it under the best microscope possible, you would see positively nothing but solid jelly, without the least sign of any organisation whatever. But this is not all. Replace these morsels in the water, and come back to look at them at the end of five, twenty, or thirty hours. Each one of them will have become a perfect bag, ready to multiply itself afresh if you submit it to the same operation. Sometimes, on some part of the original bag, there suddenly appears a little raised spot, like that which came on your baby brother's arm the other day after he had been vaccinated. What would you have said, if this ugly spot had grown larger and larger without stopping; if it had assumed legs, arms, and a head, and so become another baby, growing from the arm of the first one? Yet this is just what the spots do which come on the bag I have been telling you of; and people have come across bags of a larger species still—between one and two inches in size, in fact—which in this way carried twelve young ones on their backs, if one is allowed to talk of stomachs having *backs*. You perceive at once that this commencement of animal life is not even a digestive tube, and that nothing in it can be found but a stomach, opening straight to the air above and closed up below.

It was Réaumur, the originator of the famous thermometer, who gave a name to the wonderful bags discovered by Trembley. Aristotle had previously bestowed the title of *polypus* (many feet) upon a mollusk outwardly formed upon a similar model* with large whips disposed regularly in a circle round the mouth, and intended for a similar use, only that they have another function besides; that of carrying the body along in the capacity of feet by clinging on to the rocks with their suckers as they go. Réaumur transferred this name to the newcomers, and called them fresh-water polyps, to the infinite amusement of Voltaire, who had declared that they were only blades of grass; a new proof, among many others, that in natural history all the intellect in the world is not worth a pair of good eyes.

But it was soon found out that, in collecting these bits of living jelly near the Hague, Trembley had laid his hands on little beings of immense importance on the surface of the globe, and that he had discovered under his microscope the explanation of a mystery which had spread itself, setting human science at defiance, over some thousands of square miles.

I talked to you just now of the jeweller's coral, of which ornaments so becoming to dark-haired people are made. That is one of the stony polypidoms I spoke of as stone trees found at the bottom of the sea, where it grows attached to the rocks in the form of a charming little shrub, stretching its red branches in all directions. The Greeks, who were never at a loss, relate that Perseus one day laid down upon the sea-shore the famous head of Medusa, the sight of which had the property of turning everything to stone, and that the nymphs, in sport, showed it to the coral shrubs; a fact which explained everything quite naturally. Without exactly holding this mythological explanation, modern philosophers had not got much farther, and coral was still a puzzle to them, which they were not fond of troubling themselves about; till, roused by Trembley's revelations, they examined it more carefully, and discovered in its soft extremities (hitherto unnoticed) those same living jelly-bags or sacs, with their circlets of legs, or rather arms, charged with supplying them with food. These were marine polyps, which grow, like those in fresh water, one upon another, but each in its own crusty cell; and like the buds of the oak, these buds of the stony tree form each its special deposit, which it bequeaths in dying to the general mass. In short, as the tender shoot of the oak is filled by degrees with the wood which forms within it, and hardens into a branch, that goes on increasing by perpetually new growths, so the jelly polyp of the polypidom hardens below into stone and dies incessantly at the base, while it lives on indefinitely above in its constantly-renewed summit.

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* This is the cuttle-fish, called *polypus* by old naturalists. We shall speak of it fully hereafter in the history of the movement machine.

Do not get tired of all this phantasmagoria, my dear pupil: it is a matter of the highest interest. Here is the point of junction—the bond, as it were, between the three kingdoms: an animal growing vegetable-wise produces a mineral mass, extracted from the waters of the sea by an infinity of little living crucibles, who carry on under our eyes the work begun in the first ages of the globe, and quietly manufacture continents for the use of future generations. This ought to console you, my dear child, for being little. It is by little things that God loves to effect what is truly great. He did not seek out the elephant or the whale to form these worlds;

He chose workmen no bigger than a pin's head. I have spoken to you about jeweller's coral, which is made into toys or presents for ladies to adorn themselves with; but its brethren, the madrepores of the Pacific Ocean, play a very different part. They have formed in front of the shores of New Holland a barrier of reefs three hundred leagues in extent and twenty wide. What are all our buildings after this?—those pyramids and cathedrals which seem so gigantic to us? This ever-increasing wave of coral polypidoms will one day shut against navigators the entrance to one part of the sea's tropical region; and lands not to be found on the map to-day will then lie stretched out under the sun, covered with plants and animals; and this in places where ships now plough the ocean. Know, also, that a great portion of the soil which we tread under foot has no other origin. It was manufactured formerly in the sea by infinite myriads of beings, often infinitely small. Each one, whether polype or shell, produced its grain of stone, and from all these grains God, who directed their work, has made our country.

But it is time to bring this chattering to a close, for it will never end if I do not force myself to stop. I leave it with regret; but all these paths through which I have threaded my way one after another without counting them, have already made a volume which may possibly be considered too large for you. There are many other zoophytes besides the coral polypes, and all of them beautiful and curious. They all inhabit the fertile depths of the waters where God has deposited the first germs of life. I cannot describe them to you now. But to make amends, I will give you a piece of advice which will perhaps make some people stare. Ask your papa to lend you Michelet's book, *The Sea*, and look there for what is said about the mysterious animals which lie hid beneath the waves. His book was not written for you as this one is: and if, in spite of all my good intentions, I have not always succeeded in being as comprehensible as I meant to be, Michelet, who never thought about little people when he took up his pen, will certainly startle you now and then. But do not be disheartened by a word. You will find there, that which will be forever plain to you, the poesy of nature, and children comprehend that better than learned men.

LETTER XL.

THE NOURISHMENT OF PLANTS.

One more word before we part about the last of the eaters, about Vegetables. They will furnish you with a new and very clearly marked proof of the uniformity of the fundamental conditions to which the Author of life has subjected all organised beings.

Let us look once more at this oak, of whose manner of growth I was obliged to give you a sketch beforehand, in order to show you the ties which unite it with its immediate neighbors in the animal kingdom. How does it feed? I need not tell you this. It feeds by its roots, which suck up in the bosom of the earth the water charged with the juices which form its nourishment. Are you aware that every large branch had its subterranean fellow or representative, and that the annual shoot at the top of the tree is reproduced at the base by fresh fibres, which extend themselves in the soil of the earth, in proportion as their sisters above make their way in the air? And thus, by means of organs ever young, the life and progress of the great association is kept up, while those members whose day of work is over still remain there as the supports of the edifice. It is the same with human societies. They are sustained by what is old, but they live and progress only by what is young. The sap, then, which is the name given to the moisture or water sucked in by the young roots, having once got into the cells of which the tissue of the fibres is composed, passes from one to another, and travels thus to the top of the tree, where it is wanted by the leaves.

There is no obvious machinery here, however, to impel it forward. It journeys on of itself, as it were, under the action of laws which have never been satisfactorily explained, but all of which are dependent on the vital force or life-power of the tree, inasmuch as without it there is no circulation. One agent, but by no means the principal, or it would act as well in a dead tree as a living one, is *capillary attraction;* and, if you wish to know what that is, you have only to think of what happens to a towel, if you hang it upon a peg, and leave the end of it soaking in water. Does not the "wet" seem to climb up it thread by thread, till it is damp from one end to the other? A little in this way—but these similes are very imperfect, and will not bear close application—the sap rises in a tree, stealing up branch by branch; and it is then called *ascending sap.**

It arrives at last at the leaves, which it enters as our food enters our stomachs, and for the same purpose; for in them takes place, as in all true stomachs, that process of digestion by which the elements of the crude sap-food are decomposed from their first condition, and converted into a nourishing chyle; in each tree of a sort "after its kind."

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* M. Macé speaks of this sap as the *blood of the tree,* and of the leaves only as *lungs.* These statements have been modified so as to meet the fact that *ascending sap* consists of, and conveys the raw elements of *food* to, the leaves; that in the leaves this food is *digested,* as well as brought in contact with the air, and that it is thus converted into that nourishing fluid, the *descending sap,* which certainly plays the part of steward to the tree as our blood does to us, and therefore may now be called the blood of the tree. It must be remembered, however, that each tree has its own sort of steward, as the case of the *Euphorbia* (quoted afterwards) plainly shows. The analogy with the more general substance of blood is therefore not very complete.—Tr.

But more than this. Like the outer coat of the earthworm, the coat of the leaf affords a passage to air and moisture through its surface; and here, therefore, takes place that mysterious exchange which is everywhere the essential condition of life. Here is the charcoal-market as before, only the bargainers have changed parts. The air, which in the other case received the *carbon*, delivers it up, now, and receives oxygen in exchange; exactly the reverse of its traffic with animals. In other words, the tree inhales through its leaves the carbonic acid gas thrown into the atmosphere by our lungs. On its own responsibility it breaks through the alliance between the carbon and oxygen contracted in our organs; keeps the carbon for its own use, to restore it to us another day under the form of wood, or, by the aid of the charcoal-burner, in the pure and simple state of charcoal; and sets at liberty the oxygen, which once more goes off in search of new lungs and a fresh alliance. Thus a constant equilibrium is maintained in the atmosphere; and thus, by a system of perpetual rotation or everlasting merry-go-round, the same substances serve, indefinitely, to support life of every opposite description.

Now there are two things to be remembered in this inverted respiration of vegetables. In the first place, it occurs only in the parts which are *green*. Flowers, fruit, the root, and every part of any other color, do as we do when we breathe; *i. e.* deprive the air of its oxygen, charging it with carbonic acid instead. For which reason, by-the-by, we ought not to keep flowers in a bedroom at night. Charming as they are, they are *poisoners*, and a headache is what we may fairly expect after sleeping shut in with them in the same room. It is almost as bad to allow green boughs to remain there either, for, in the dark, even the green parts cease to purify the air, and begin like the others to manufacture carbonic acid, at the expense of course of their carbon, which thus by degrees is used up. Now, as it is the carbon which constitutes the solid fibres of plants and produces their green color, they soon become yellow and limp when deprived of light. You may, perhaps, have wondered why the gardener amused himself with smothering his poor lettuces by tying them up at top like a knot of "back hair," instead of letting them grow freely in the air and sunshine. It is, my dear, to make them more tender and delicate for you to eat; and those beautiful, crisp, yellow leaves, so delicious to the tooth, would have been green and tough, had they not slowly and quietly let out a great portion of their store of carbon in darkness during the last few days, before being gathered. Even without playing the gardener, you may assure yourself of this fact in a still more simple manner. Put a flat board upon the lawn and leave it there for three days; then take it up again, and you will find just where the board has prevented the light from reaching the grass, a yellow mark so distinctly traced as to be seen from the other end of the garden.

But to return to the sap, which we left undergoing a change from air and solar influences in the leaves. The ascending sap was to all appearance only clear water. When it returns from the leaves, charged with carbon, it is a thick juice having almost the consistency, and sometimes even the color of milk, and is possessed of properties altogether new. The most striking example that I can give you of the difference of the two states of sap is the Euphorbia of the Canary Islands, whose digestive or descending sap is a violent poison. When the natives of the country are accidentally pressed by thirst, they carefully remove the bark in which the fatal juice circulates, and are then able to refresh themselves safely by sucking the stem, which yields only the watery sap sucked from the ground, and as yet unaltered and harmless.

Each of these two saps, in fact, has its path distinctly traced for it: the first rises through the wood, the second descends through the bark, whence it is called descending sap. If you wish to satisfy yourself of this, fasten a rather tight knot of pack-thread round a young branch, and after a time you will see it pine below the knot and become swollen above it, an unanswerable proof that the nutritive juices flowed downward through the bark; for the wood inside the branch will have been uninjured by the strangling pressure. Remember this, my dear, when you are playing in the garden, and do not injure the bark of the young trees your father likes so much to see flourishing. It is by the bark that they are nourished, and you might even kill them by treating it too roughly.

And now I must show you how the nutrition is carried on, or, if you like better, how the tree grows by means of this descending sap. See: here is a fir tree, which has just been cut down to the ground. Now, if you like, I will tell you in a moment how old it is. I will even tell you the age of every branch, little and big ones both, without making a mistake in a single year; and you know as well as I do that I am no conjuror. You see these small circles so delicately drawn, as it were, upon the face of the sawn trunk, each wider than the last, as if they were composed of a set of tubes, of un-equal sizes, fitting exactly into each other. Now count them; and you will perhaps find twenty-five; and as each of these circles represents the work of one year, you will know that the tree is twenty-five years old. In spring, when the sap begins to move more briskly, it deposits everywhere between the wood and the bark, from the trunk to the farthest boughs of the tree, a uniform layer of a thick liquid, which moulds itself exactly upon the wood already formed. This layer stiffens during the year; it gets filled with the carbon left in it atom after atom, by each drop of the descending sap as it goes by, and thus insensibly becoming organised and hardened. When winter arrives to interrupt the work, it will have formed two *ligneous*, *i. e.* woody layers, as they are called. Of these, one belongs to the wood, and will never move again so long as the tree lasts, for it will be covered over, and as it were buried, by the successive layers yet to come; while, on the contrary, the other (layer) belongs to the bark, and is doomed to find itself perpetually forced outwards by the fresh layers, which will after a while insinuate themselves between it and the wood.

It is for this reason that the bark of old trunks of trees is so deeply furrowed, and that the dry scales may be picked off the surface without the slightest injury to the tree. It is part of the original bark, dead long ago. The old wood also is dead inside, and even when it is altogether gone, the glad youthful branches growing green in the sunshine will scarcely find it out! This accounts for those oaks which time has hollowed without destroying, as those of Allonville in Normandy, in which mass is said, and which is moreover the greenest tree in the country. But without going so far, who has not seen those hollow old willows, sometimes pierced with holes letting in daylight, yet proudly crowned above by a forest of young boughs, as green and full of vigor as if the trunk were still in its prime? What was dead has departed, but all that has life in it remains, and that is enough for the tree.

Need I add that the descending sap, this steward of the vegetable, has also his workmen to supply with materials, as in our case, and that he is always falling in on his road with organs, all of which want different things from him? That here a flower has to be formed, there a fruit, there a leaf, or a bit of wood, and so on: and that a mysterious intelligence—the same that we have found everywhere else—presides over all these varied constructions, the materials for which are mixed together pell-mell, in the imperceptible thread of sap which oozes from the leaf to the bark? I recollect just as I am about to conclude, my dear child, that I once told you, you were a small temple in which God perpetually attests His presence, by a permanent miracle. You may now henceforth look upon a tree as something more than a bit of wood, yielding a pleasant shade. God is in it also.

CONCLUSION.

And now, my dear little pupil, to what conclusion do we come from all this? To that which I announced to you from the first. Throughout the length and breadth of creation, from the highest to the lowest grade, every living thing is subject to the same law. Everything eats, and eats nearly in the same manner, since everywhere the same substances furnish the feast. I laid down in my first letter that our feeding machine was reproduced even to the farthest limits of the animal kingdom, though always becoming more simple as the species descends in the scale. And afterwards, where we began the study of animals, I told you that in this machine lay the uniformity of their construction. Was I not right? and what could I add to all the proofs which have developed themselves one after another, to establish the fact of this uniformity of plan in the animal machine, in all its essential points? And it will be to the lasting renown of the illustrious Geoffroy St. Hilaire that it was, in the face of all the Academies and under the fire of very learned indignation, he proclaimed this truth, which one cannot lose sight of without losing one's way in a crowd of arbitrary fancies.

I return, then, to the definition which I gave you in speaking of the worm, and which is the final word of the ideas I have been endeavoring to make you understand. *An animal is a digestive tube served by organs.*

In the first place it must eat, and for this therefore the Creator provided first. All the rest came afterwards in order to enable it to eat more readily, to secure its prey more easily, and to make the most of it when eaten. The movement machine, therefore, whose history I have promised you, is only an assistant, and not the principal feature of the organisation, and it is not by it, therefore, that the question can be decided, whether God has made three, four, or five animals, or whether he has only made one.

And now, my dear little pupil, I will bid you adieu, or rather say as the French do, "Au revoir," which means "Good-bye till we meet again," begging you to excuse any awkward expressions that may have escaped me, as also my having now and then talked about things because they have interested me, without perhaps sufficiently considering whether they might have an equal interest for you. Yet, while the pen is still in my hand, I will not leave you my concluding definition of an animal without adding a word of explanation. You know nothing about such matters yourself, but to some people my words might have the air of a parody upon another definition, applied by those grave gentlemen the Philosophers to man, whom they have denominated *An intelligence served by organs.* My definition is applicable only to the animal, and not to man, observe. Man in the natural, physical machinery of his body, is very decidedly an animal; yet as certainly is he, by the divine reflection which shines within him, something much more and greater; but *what*, is so far beyond the reach of definition that I shall not attempt to give you one. "Man," as Jesus Christ has said, "lives not by bread alone, but by every word that proceedeth out of the mouth of God." What it is that is nourished in us by that word, is precisely what I cannot attempt to define for you; yet I think you have understood my meaning.

Go, then, and eat your food in peace, like the pretty little animal that you are; but do not forget to nourish also the other part of your being; that indeed which is of the most importance, and which enables you to ascend to your Creator.

THE END.

POSTSCRIPT.

In going through the preceding pages (Part II.) with a comparative anatomist, it became evident that some few popular and other errors and misconceptions had crept into this portion of M. Macé's usually clear and accurate work.

Naturally it was not in his power to verify all the statements he had to make on so many and such varied subjects, and he appears occasionally to have trusted to works of old-fashioned or doubtful authority.

In these cases I have considered it desirable to make such corrections as should secure the trustworthiness of the descriptions as far as they pretend to go.

It would not, however, have been in my power to accomplish this, but for the kind and efficient aid I have received from a scientific student of these subjects; and I am glad of this opportunity of acknowledging how much I am indebted to him for his assistance in making the necessary alterations, as well as for confirming the correctness of the greater portion of the work.

MARGARET GATTY.

January, 1865.